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TECHNICAL REPORT HL-79-7

NAVIGATION CONDITIONS ON THE LOWER CUMBERLAND RIVER, KENTUCKY

Hydraulic Model Investigation

by

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March 1979

Final Report

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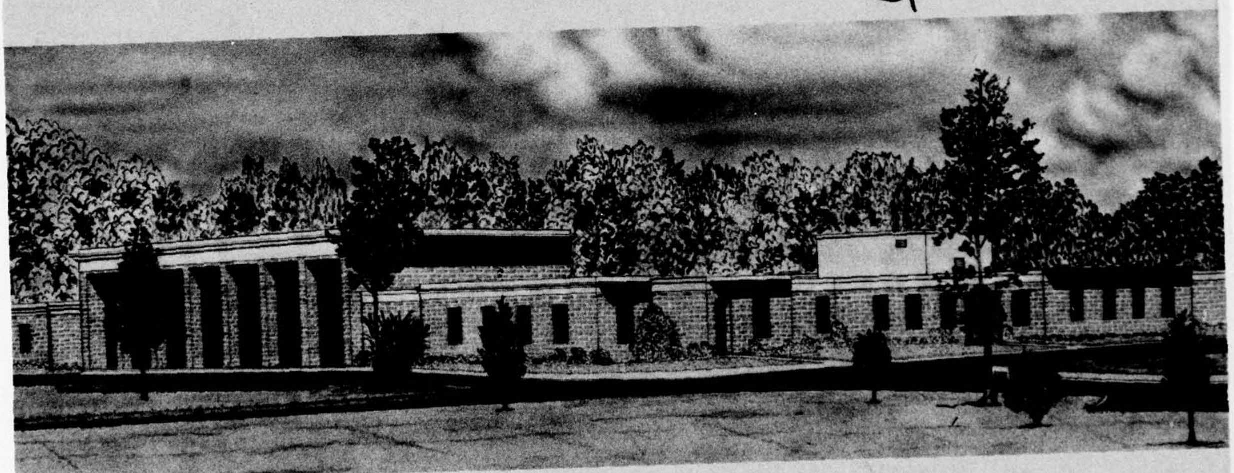

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This study is concerned with a short reach of the Cumberland River just downstream of Barkley Lock and Dam. The reach is narrow and of irregular alignment with some very sharp bends and two fixed-span highway bridges, one located just downstream of the lower lock approach and the other located just downstream of a sharp bend. Currents in the reach are affected by continuous changes in powerhouse releases and changes in stages on the Ohio River located about 30 Con't

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20. ABSTRACT (Continued).

CONT

miles downstream of the dam. The model investigation was primarily concerned with navigation conditions in the lower lock approach and in the reach downstream and with the development of plans as required to provide satisfactory navigation conditions for both upbound and downbound traffic.

A fixed-bed model reproducing Barkley Dam, the powerhouse, the portion of the lock downstream of the dam, and about 7.3 miles of the Cumberland River to an undistorted scale of 1:120 was used for the investigation. Results of the investigation indicated that with existing conditions navigation conditions are difficult and hazardous for large tows and are affected by changes in powerhouse releases, eddy currents, high velocities, and sharp bends. Conditions could be improved by increasing the interval between the increase or decrease of the number of powerhouse units in operation, adding dikes downstream of the powerhouse and lower lock guard wall, and increasing the width of channel and realignment of the banks in the sharp bends. Increasing the tailwater elevation with control structures would produce only limited navigation benefits, particularly during higher flows, and would substantially decrease the head available at the powerhouse.

PREFACE

The model investigation reported herein was authorized by the Office, Chief of Engineers, U. S. Army, in 2d Indorsement dated 12 May 1975 to the Division Engineer, U. S. Army Engineer Division, Ohio River. The study was conducted for the U. S. Army Engineer District, Nashville, in the Hydraulics Laboratory of the U. S. Army Engineer Waterways Experiment Station (WES) during the period November 1975 to December 1977.

The investigation was performed under the general supervision of Messrs. H. B. Simmons, Chief of the Hydraulics Laboratory, and F. A. Herrmann, Jr., Assistant Chief of the Hydraulics Laboratory, and under the direct supervision of J. E. Glover, Chief of the Waterways Division. The engineer in immediate charge of the model was Mr. L. J. Shows, Chief of the Navigation Branch, assisted by Messrs. R. T. Wooley and J. M. Ross. This report was prepared by Messrs. Shows and J. J. Franco.

During the course of the model study, Messrs. W. H. Andrew and R. J. Connor and others from the Nashville District visited the WES at different times to observe special model tests and to discuss test results. Visits were also made by representatives of navigation interests. The Nashville District was kept informed of the progress of the study through monthly progress reports and special reports.

Directors of WES during the course of the investigation and the preparation and publication of this report were COL G. H. Hilt, CE, and COL John L. Cannon, CE. Technical Director was Mr. F. R. Brown.

CONTENTS

CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
cubic feet per second	0.02831685	cubic metres per second
cubic yards	0.7645549	cubic metres
feet	0.3048	metres
feet per second	0.3048	metres per second
miles (U. S. statute)	1.609344	kilometres

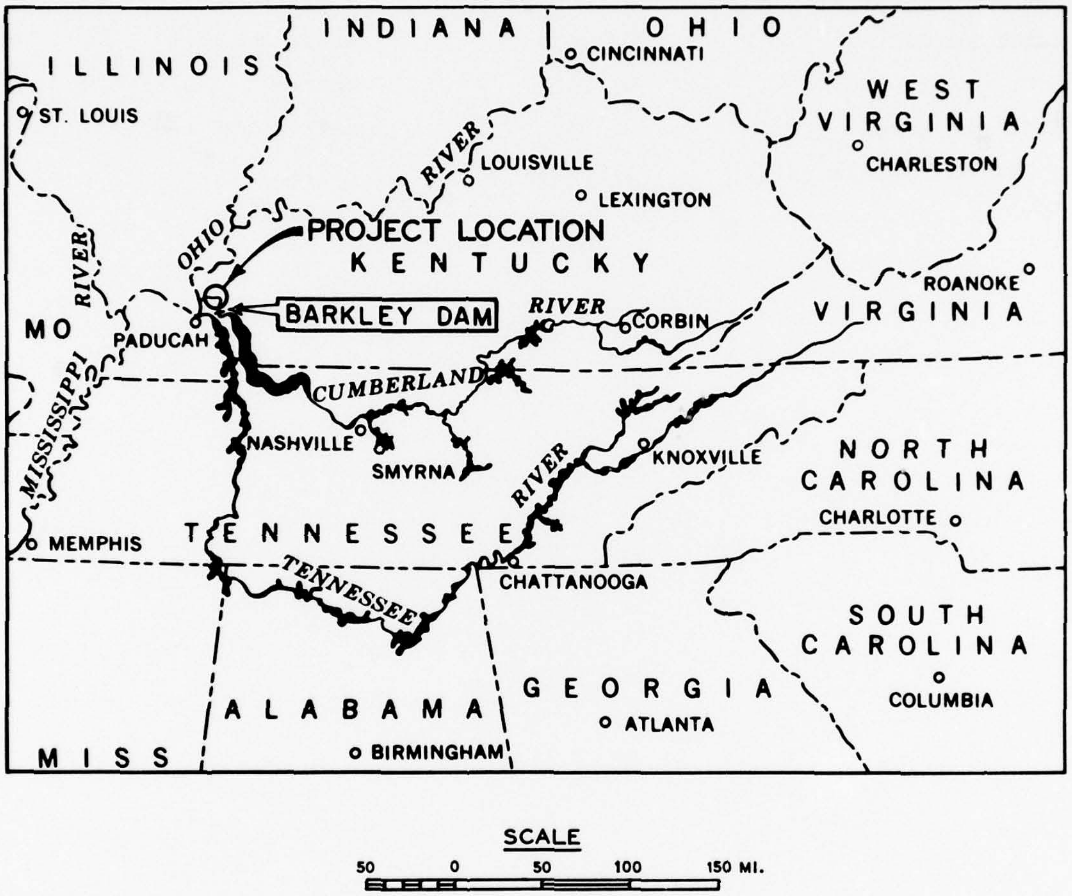

Figure 1. Vicinity map

NAVIGATION CONDITIONS ON THE LOWER CUMBERLAND RIVER, KENTUCKY

Hydraulic Model Investigation

PART I: INTRODUCTION

Location and Description of Prototype

1. The Barkley Lock and Dam project, which includes a powerhouse, spillway, and a 110- by 800-ft* lock, is located on the Cumberland River, 30.6 miles above its mouth where it joins the Ohio River at mile 920.5. The Tennessee Valley Authority's (TVA) Kentucky Lock and Dam which has a 110- by 600-ft lock is located adjacent to the Barkley project on the Tennessee River about 22.4 miles above its mouth where it joins the Ohio River at mile 932.5. A few miles upstream of the dams, the lakes for these two projects are joined by a 1.5-mile-long open navigation canal, that provides for the interchange of navigation between the two rivers (Figure 1).

2. Nearly all commercial traffic moving in either direction in the last several years has been using the lower Tennessee River route. Large tows coming out of the Barkley pool with destinations up the Ohio River use the Tennessee River route, even when lockage delays of more than 6 hours are expected at Kentucky Lock. The navigation conditions along the Cumberland River route below Barkley are far less favorable than those below the Kentucky project, and are characterized by sharp bends, restricted channel widths, variable currents, and varying water levels.

3. Under present traffic patterns and with the growth rate trends established, it is probable that the capacity of the Kentucky Lock will be severely taxed if not exceeded in the near future. In the absence of improvements in the lower Cumberland River, the newer and larger

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* A table of factors for converting U. S. customary units of measurement to metric (SI) can be found on page 3.

Barkley Lock will have excess capacity.

4. The authority for this investigation is a resolution sponsored by Senator John Sherman Cooper and adopted by the Committee on Public Works, United States Senate, on 2 October 1972. The text of the resolution reads as follows:

> "RESOLVED BY THE COMMITTEE ON PUBLIC WORKS OF THE UNITED STATES, that the Board of Engineers for Rivers and Harbors, created under Sec. 3 of the River and Harbor Act, approved June 13, 1902, be, and is hereby, requested to review the reports of the Chief of Engineers on the Cumberland River, Kentucky and Tennessee, published as House Document Numbered 761, Seventy-ninth Congress, second session, and Senate Document Numbered 81, Eighty-third Congress, second session, and the report of the Chief of Engineers on the Tennessee River and tributaries, North Carolina, Tennessee, Alabama, and Kentucky, published as House Document Numbered 328, Seventy-first Congress, second session, and other applicable reports on both rivers with a view to determining what improvements to the Cumberland and Tennessee Rivers, generally below the connecting Barkley Canal, and their relation to the inland waterways system, are advisable for navigation and other purposes at the present time."

Need for and Purpose of Model Study

5. Preliminary studies conducted jointly by the U. S. Army Engineer District, Nashville, and the TVA to determine what immediate and long-range measures could be taken to alleviate navigation conditions on the lower Cumberland and Tennessee Rivers indicated the need for more detailed studies to develop a more permanent solution to the problems involved. The preliminary investigation resulting from the resolution indicated that the detailed studies should be concerned with long-range improvements and changes in operating regulations which would provide increased utilization of Barkley Lock and additional lock capacity at Kentucky Lock. Since the lower Tennessee River is to be included in the study area, the investigation would be a joint effort between the Nashville District and the TVA. The following studies would be required:

_a_. Physical and mathematical model studies of the lower Cumberland River channel should precede traffic and formulation studies in order to better identify the critical alignment constraints, safety risks, and incremental changes attributable to alternative improvements.

_b_. Traffic studies to determine projected commodity movements on the lower Cumberland-Tennessee waterway system and to include an analysis of this element as an integral portion of the Nation's inland waterway system.

_c_. Alternative structural and nonstructural measures to be investigated to determine the most feasible means of meeting the study objective.

_d_. Economic studies to evaluate alternative waterway improvements to determine benefits that will accrue to navigation interests.

_e_. Geologic studies to determine subsurface conditions and necessary foundation treatment for structural measures, stability analysis for locks and channel improvements, and sources of construction materials.

_f_. Environmental studies to include an assessment of existing conditions and the potential impact of alternative plan of improvement.

_g_. Real estate studies to analyze the right-of-way requirements for selected plans and to determine the cost estimate for all lands, easements, and rights-of-way required.

6. A physical model study was considered necessary to determine the effects of powerhouse releases on navigation conditions in the lower approach to the Barkley Lock, and in the reaches downstream, and to develop modifications that could be used to eliminate or minimize any undesirable conditions indicated.

PART II: THE MODEL

Description

7. The model (Figure 2) reproduced about 7.3 miles of the Cumberland River, extending from about 1,000 ft upstream of the dam (mile 30.8) to about mile 23.5 downstream including Barkley Dam, powerhouse, and most of the lock. The model was of the fixed-bed type, with the channel and overbank areas molded in sand-cement mortar to sheet-metal templates. Portions of the model, where changes in bank alignments and channel configurations could be anticipated, were molded in pea gravel to facilitate modifications that might be required to improve the reach. The lock, dam, powerhouse, and bridges were fabricated of sheet metal. The dam gates were simulated schematically with simple sheet-metal slide-type gates. The powerhouse units were equipped with simple valves that could be operated to reproduce variations in powerhouse releases.

8. The channel portion of the model was molded to conform to a special hydrographic survey dated September 1975 and the overbank areas were molded to a topographic survey dated 1967. Except in the upper reach, overbank areas were reproduced to a top elevation of 330* which was sufficient to permit the investigation of flows that would affect navigation. Overbank areas near the upper reach of the model were reproduced to elevations somewhat higher.

Scale Relations

9. The model was built to an undistorted linear scale ratio of 1:120 model-to-prototype to obtain accurate reproduction of velocities, crosscurrents, and eddies that would affect navigation. Other scale ratios resulting from the linear scale ratio were as follows:

Area	1:14,400
Velocity	1:10.95

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* All elevations (el) cited herein are in feet referred to mean sea level (msl).

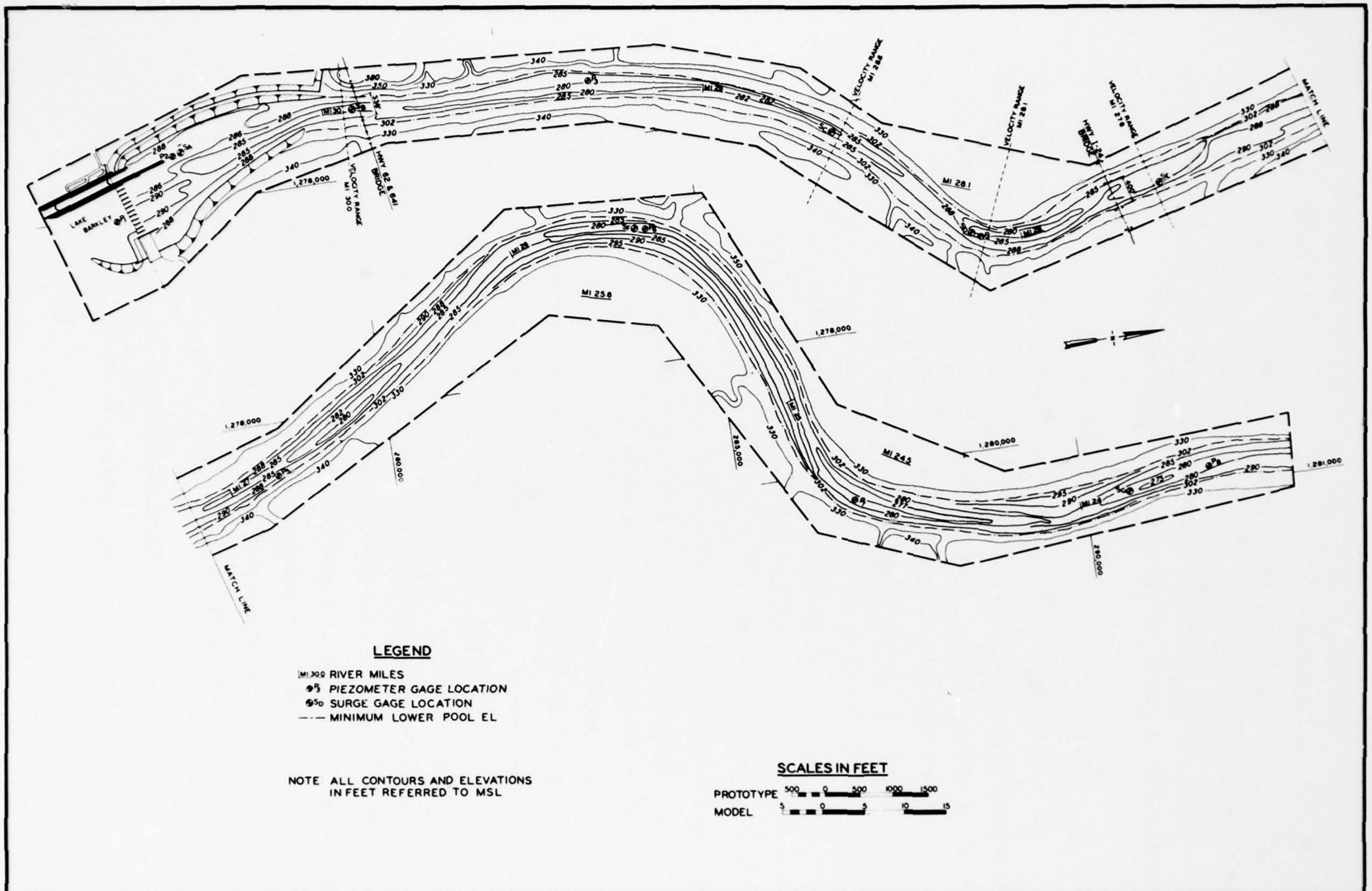


Figure 2. Model layout

Time	1:10.95
Discharge	1:157,743
Roughness (Manning's n)	1:2.22

Measurements of discharges, water-surface elevations, and current velocities can be transferred quantitatively from model to prototype equivalents by means of these scale relations.

Appurtenances

10. Water was supplied to the model by means of a circulating comprehensive water supply system; the discharge was controlled and measured at the upper end of the model by means of valves and venturi meters. Water-surface elevations were measured by means of piezometer gages located in the model channel and connected to individual pits located along the side of the channel (Figure 2). Surges were measured with continuous recording gages placed at selected ranges. Tests were conducted by controlling the discharge through the powerhouse and spillway gates and by controlling tailwater elevations by means of a tailgate located at the lower end of the model.

11. Velocities and current directions were determined in the model by means of floats consisting of wooden cylinders weighted on one end so that they would be submerged to a depth of a loaded barge using the waterway (9 ft prototype). Spot velocities were measured with a miniature current meter. Model towboats with tows, 105 ft wide and 1,200 ft long, loaded to a draft of 9 ft were used to determine and demonstrate the effects of currents on traffic moving through the reach and entering and leaving the lock (Figure 3). The towboats were equipped with twin screws and propelled by two small electric motors operating from batteries located in the tow; the rudders and speed of the tows were remote-controlled. The power of the towboats was adjusted by means of a rheostat to a maximum speed comparable to that of towboats expected to use the Cumberland River.

Model Adjustment

12. Before the study was undertaken, the model was checked and

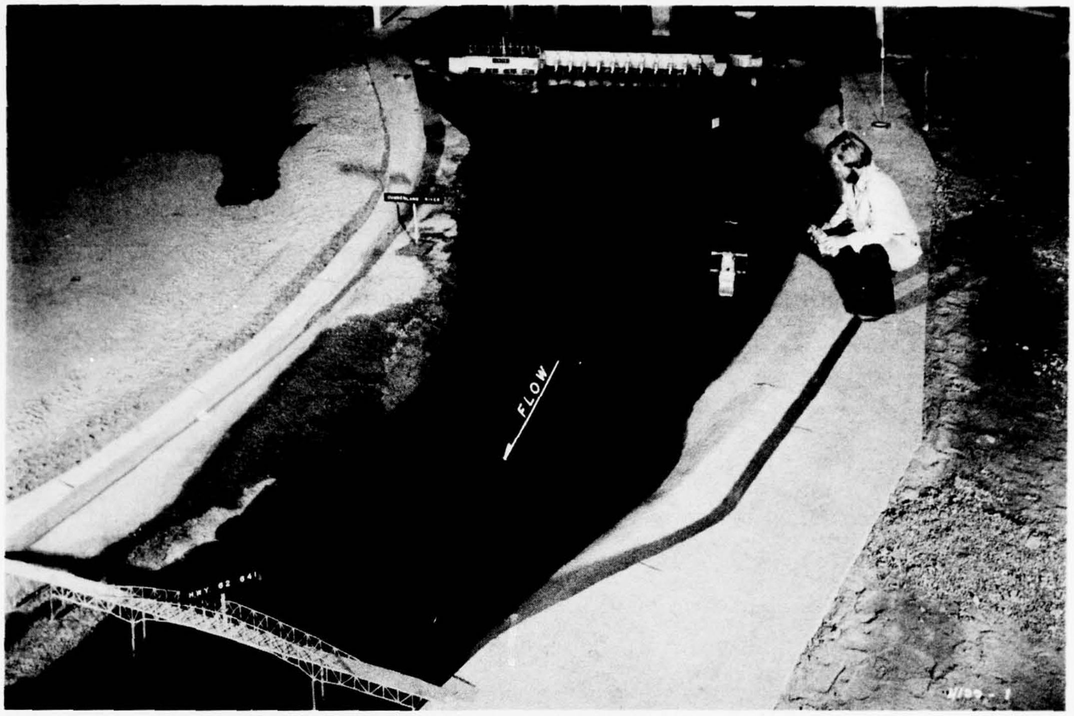


Figure 3. Remote-controlled towboat and tow approaching the lock

adjustments were made where necessary to reproduce conditions in the prototype. Most of the adjustment was concerned with the controlling of water-surface elevations at the lower end of the model to correspond with the varying powerhouse releases and development of an operating procedure. The model was constructed with a brushed-cement mortar finish to provide a roughness factor (Manning's n) of about 0.0135, which corresponds to a prototype channel roughness of about 0.030. Experience with other models of this type has indicated that brushed concrete provides a reasonably close approximation of the roughness required to reproduce prototype conditions. After adjustment of the model and development of a suitable operating technique, the model reproduced surges, water-surface elevation, and current velocities reasonably close based on the prototype information available, as indicated in Plates 1-6.

PART III: TESTS AND RESULTS

13. Tests were concerned primarily with the study of flow patterns, measurement of velocities and surges, and the effects of the currents on the movement of towboats approaching and leaving the lower lock approach and in the critical reaches downstream. Tests were conducted with various discharges as affected by powerhouse releases with and without flow through the dam. The effects of lock emptying were not considered in these tests.

Test Procedure

14. Powerhouse tests were conducted starting with one unit in operation (10,250 cfs) and tailwater el 302.5 and then adding the remaining three units at 1-hr intervals which increased discharge in increments of 10,250 cfs up to a total of 41,000 cfs. Continuous water-surface elevations and velocity measurements were obtained at eight ranges located at miles 30.5, 30.0, 28.6, 28.1, 27.6, 25.6, 24.5, and 23.8 (ranges 1-8, respectively). Prototype data were available at only four of these ranges (miles 30.0, 28.6, 28.1, and 27.6) which could be used for comparison with model results.

15. Tests were also conducted with flow through the gated spillway and varying discharge through the powerhouse. The flows were selected to be representative of conditions that have occurred in the prototype and could be expected in the future. These flows were reproduced as listed below.

Range No.	Discharge, cfs Powerhouse	Spillway	Total	Tailwater Elevation*
1	10,250(1)**	None	10,250	301.3
2	20,500(2)	None	20,500	302.6
3	40,320(4)	None	40,320	310.7

(Continued)

* Computed tailwater for lower end of model reach (gage 8) including effect of Ohio River stage.

** Number in parentheses indicates number of power units in operation.

Range No.	Discharge, cfs Powerhouse	Spillway	Total	Tailwater Elevation
4	55,000(4)	None	55,000	314.1
5	55,000(4)	None	55,000	317.1
6	55,000(4)	25,000	80,000	320.7
7	55,000(4)	45,000	100,000	325.2
8	55,000(4)	65,000	120,000	333.6

16. The flows selected for testing the effectiveness of the various plans and modifications were based on information presented during conferences with representatives of the Nashville District and navigation interests. It was indicated during these conferences that most of the navigation difficulties were caused by the high-velocity currents and sharp bends with narrow channel occurring mostly during alternate operation of the power units with low flows and low stages on the Ohio River. Accordingly, most of the plans were tested with one powerhouse unit in operation (10,250 cfs), with four powerhouse units in operation (55,000 cfs) which occurs for a considerable period of time each summer, and with a flow of 80,000 cfs consisting of four powerhouse units in operation and 25,000 cfs over the spillway.

17. Flows were reproduced by introducing the proper discharge and manipulating the tailgate until the tailwater elevations for the flows reproduced were obtained. All flows were permitted to stabilize (except during surge tests) before any data were recorded and are considered as constant flows. Current directions were determined by plotting the paths of floats with respect to ranges established for the purpose, and velocities were determined by timing the travel of floats over known distances. Where eddies and crosscurrents were encountered, plots indicate only the principal trends in the interest of clarity. No data were obtained with the model towboat and tow, except to observe and record on video tape and multiexposure photographs its behavior as affected by currents in various reaches and in the lower lock approach, and in some cases the time required to negotiate the reach.

18. Most of the modifications tested were developed during

preliminary tests. Data obtained during these tests were sufficient only to assist in the development of plans that appeared to produce significant improvements and the results are not included in this report.

Base Test

Description

19. The base test was conducted with the model reproducing existing prototype conditions and operated by reproducing the various representative flows (Figure 4). Purposes of this test were to determine navigation conditions with various flows that could be expected in the reach and to obtain data that could be used to determine the effectiveness of various plans and modifications designed to eliminate any undesirable conditions indicated.

20. The first series of tests was concerned with the operation of the powerhouse with no flow through the spillway. These tests were started with one powerhouse unit in operation (10,250 cfs) and operated as follows:

- a. Remainder of units (2, 3, and 4) placed in operation at 1-hr intervals and all four units closed off after the fourth unit was in operation for 4 hr. Two hours after all units were closed, three units were placed in operation simultaneously (Plates 1 and 2) and remained in operation for 6 hr before units 2 and 3 were closed at 1-hr intervals (hydrograph 1).
- b. Remainder of the units (2, 3, and 4) placed in operation at 2-hr intervals and after 9 hr operation with the four units, the units were closed at 1-hr intervals (Plates 3 and 4, hydrograph 2).
- c. Remaining units (2, 3, and 4) placed in operation simultaneously (Plates 5 and 6, hydrograph 3).

21. The second series of tests was conducted with constant flows to obtain current direction and velocities. These flows were conducted with only powerhouse unit 1 in operation, with only unit 4 in operation, and with each of these units having some flow through the spillway. The higher flows were conducted with 55,000 cfs through the powerhouse and flows in excess of that amount distributed evenly through the spillway gates.

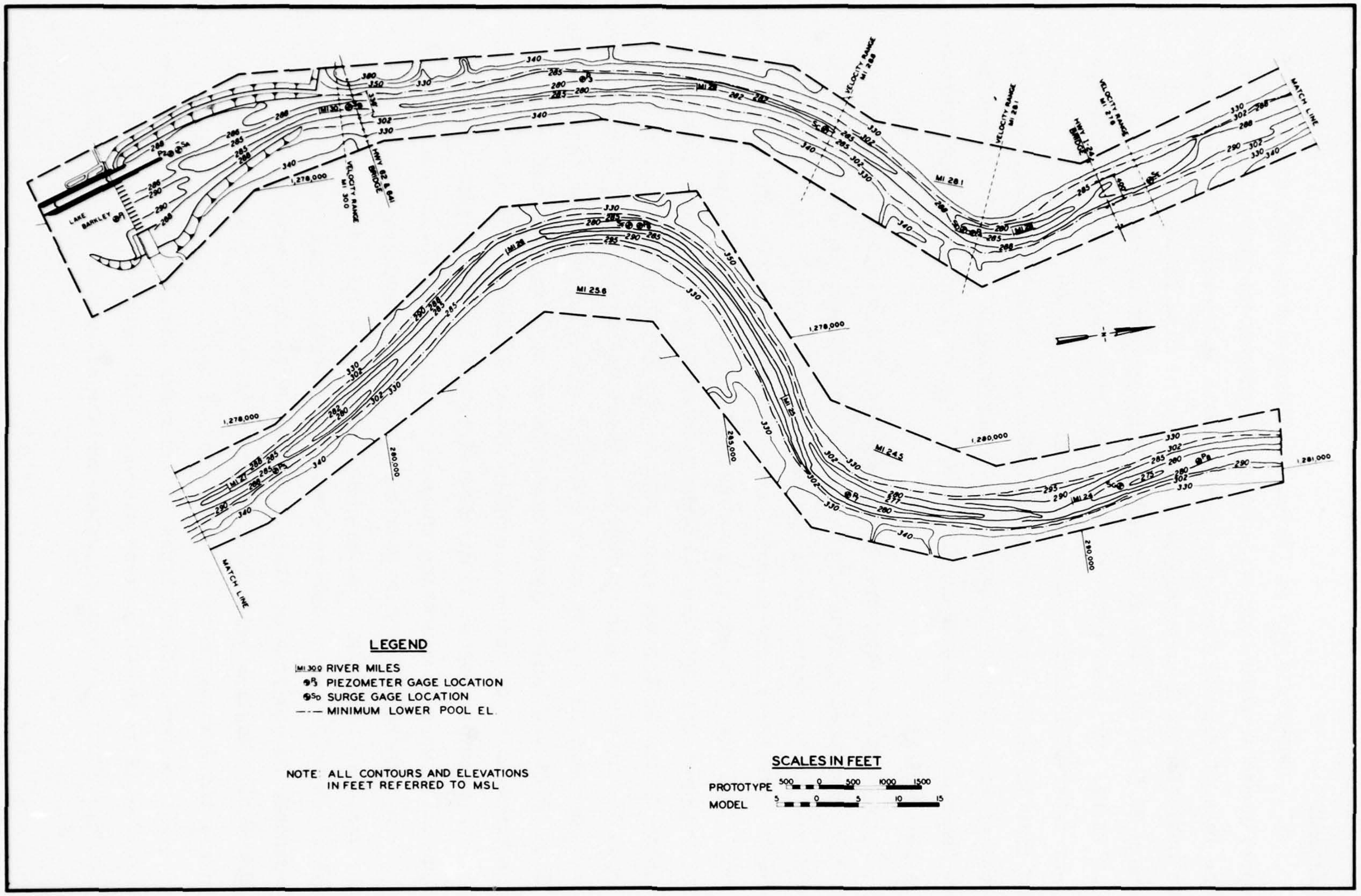


Figure 4. Existing conditions

Results

22. Results shown in Plates 1-6 indicate that most of the differences noted from the various methods of powerhouse operation were in the rate of rise in the water level. With the powerhouse units placed in operation at 1-hr intervals, the rate of rise in water level at range 30.5 was about 3 ft/hr and at 2-hr intervals, the rate was about 1.7 ft/hr. The rate of rise decreased after about 2-1/2 hr with the 1-hr interval and after about 5-1/2 hr with the 2-hr interval. Rate of rise in water surface decreased with the distance downstream. The rate of rise in water level with the three units placed in operation at the same time was about 7.5 ft/hr for the first hour, then decreased rather rapidly.

23. Results from the first series of tests indicate that the model reproduced closely the water-surface elevations and velocities measured in the prototype at ranges 30.0, 28.6, 28.1, and 27.6. The small differences between model and prototype were probably due to local conditions and lock emptying which were not considered significant. The measurements indicate that the greatest surge occurred just downstream of the lock lower guard wall (range 30.5) with all of the various schedules of powerhouse operation. There was an increase in water level of from about 10 ft with units placed in operation at 1-hr intervals to about 12 ft with units placed in operation at 2-hr intervals and with the three units placed in operation simultaneously. The difference in the water level reached is attributed to the length of time that the four units were in operation rather than in the method of operation.

24. There was little difference in the maximum velocities with the various schedules of powerhouse operation which varied from about 6.5 to about 7.0 fps. The time to reach these maximum velocities was dependent on the rate at which the powerhouse units were placed in operation. Maximum velocities occurred at range 30.5 and decreased toward the downstream to about 4.0 to 5.0 fps.

25. Water-surface slopes in the reach downstream of the dam would be affected by the Ohio River stages. With average to low flows in the Ohio River, the drop in water-surface elevations in the reach

reproduced in the model (gages 2-8) varied from about 1.2 ft with one powerhouse unit to about 4.2 ft with the 80,000-cfs flow after the flows had stabilized (Table 1).

26. Current directions and velocities obtained with steady flows are shown in Plates 7-16. With powerhouse unit 1 or unit 4 (10,250 cfs) in operation, a large eddy would form downstream of the dam and extend into the lower lock approach (Plates 7 and 8). The intensity of the eddy and crosscurrents in the approach were somewhat greater with unit 1 in operation than with unit 4. Operation of one powerhouse unit with a discharge of 10,250 cfs through the third spillway gate to the right of the lock would reduce the size of the eddy in the lock approach but would increase velocities downstream, particularly with unit 1 in operation (Plates 9 and 10).

27. The alignment of currents with all powerhouse units in operation and discharges of 40,320 to 120,000 cfs were generally parallel to the bank lines except in the lower lock approach and in some of the bends (Plates 11-16). Maximum velocities approaching the Hwy 62 and 641 Bridge varied from about 4.8 fps with all four powerhouse units in operation (40,320 cfs) to about 7.0 fps with a flow of 120,000 cfs. In the three bends downstream of the bridge (ranges 30, 57, and 69), maximum velocities varied from 5.3 to 5.5 fps in the upper two bends to as much as 7.0 fps in the lower bend with the four powerhouse units in operation. With the high discharge (120,000 cfs), maximum velocities in the three bends varied from about 7.6 to about 8.1 fps.

28. Navigation conditions in the lower lock approach are affected by the alignment and velocity of currents. With flow through the powerhouse, a large eddy formed downstream of the dam which extended into the lower lock approach. The eddy produced upstream currents along the bank in the approach which moved riverward downstream of the end of the guard wall. These currents adversely affected upbound tows approaching the lock. A tow approaching the lock at reduced speed would tend to be moved riverward by the eddy currents as it approached the end of the guard wall. The size of the eddy and its effect on the movement of upbound tows would be greater with one powerhouse unit in

operation than with all units. When one powerhouse unit is in operation, conditions would be better with unit 4 in operation than with unit 1. The size of the eddy was reduced with an equal amount of flow through the third gate bay from the lock when one unit was in operation but velocities would be increased and could be hazardous to navigation, depending on the alignment of the tow approaching the lock.

29. Downbound tows with adequate power and maneuverability could navigate the reach downstream of the lock without serious difficulties. However, because of the high-velocity currents and short radius bends, downbound tows would have to flank to negotiate the three bends near ranges 30, 57, and 69.

30. Surface currents with a constant flow of 55,000 cfs through the powerhouse and low stages on the Ohio River are shown in Photo 1. This flow occurs for a considerable length of time during each summer and was selected in conference with representatives of navigation interests and the Nashville District as a reasonable flow to be used in testing the effectiveness of various proposed modifications. The paths of upbound and downbound model tows navigating the reach downstream of the lock with this plan are shown in Photos 2-9. In order to provide a basis for determining the relative effectiveness of any improvements, the times required to navigate the reach with the model towboat and tow were determined. Results with existing conditions were as follows:

	Time, hr	
	Discharge, cfs	
Direction	55,000	80,000
Upbound	1.65	1.78
Downbound	1.35	1.23

The times indicated were based on results of several runs with the model towboat and tow which had the power limited to that required to negotiate the reach without independent control of the screws and without the use of any special steering devices. These results are presented for comparative purposes only and can vary with conditions and with size, configuration, and maneuverability of tows.

Existing Conditions-Modified

Description

31. Initial modifications were designed in an effort to improve the alignment of the currents in the lower lock approach and particularly to reduce the size and intensity of the eddies formed with the powerhouse flows. The modifications were developed during a number of preliminary tests in which the alignment, length, and elevations of the structures were varied until some significant improvements were indicated. The features of this modification were as follows (Figure 5):

a. A longitudinal dike was added, forming an extension to the left abutment wall between the powerhouse and dam. The dike was straight and in line with the abutment wall downstream to sta 4+50 and then angled 20 deg riverward and extended 400 ft downstream. Top of dike was at el 303.

b. A vane dike 600 ft long with top at el 303 was placed downstream of the dam between sta 14+00 and 20+00. The dike was 350 ft riverward of the lock center line and parallel to the alignment of the lock.

Results

32. Results shown in Table 2 indicate that the two dikes had little or no effect on water-surface elevations downstream of the dam compared with conditions without the dikes. Current directions shown in Photo 10 and Plates 17-22 indicate that there was a considerable improvement in the alignment of the currents in the lower lock approach with various powerhouse units in operation.

33. The eddies in the lower lock approach were not eliminated, but their sizes and intensity were reduced and the alignment of the eddy currents were generally parallel to the bank line. Upstream current velocities along the left bank downstream of the lock guard wall varied from less than 0.5 fps to about 1.8 fps with the 55,000-cfs powerhouse flow. Velocities in the eddy currents were somewhat higher with only unit 4 in operation than with only unit 1. Eddy currents with flows of 80,000 to 120,000 cfs were generally less than 1.0 fps and the sizes of the eddies were smaller than with only powerhouse flows. There was also a general improvement in the alignment of currents

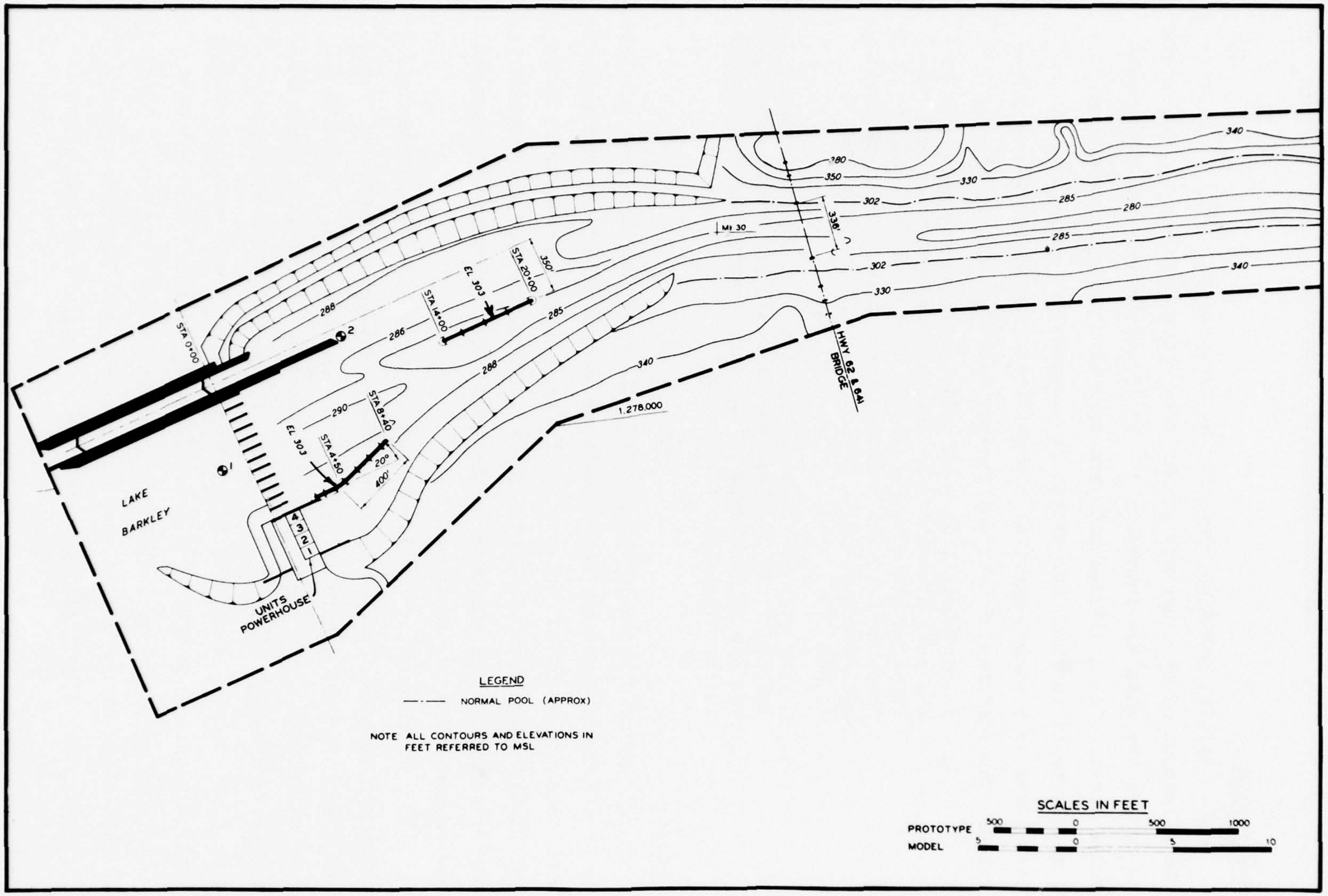


Figure 5. Existing condition-modified

approaching the bridge just downstream of the lock.

34. Photo 11 indicates typical paths of tows approaching and leaving the lock with one powerhouse unit in operation. Navigation conditions with the dikes were considerably better than those without the dikes in the lock approach and no serious difficulties were indicated. Also, downbound tows could approach the bridge downstream of the lock from midchannel and pass through the bridge near the center of the span. Upbound tows could pass through the bridge and approach the lock with considerably less difficulty and maneuvering.

Plan A

Description

35. Plan A was the same as existing conditions except for the modification of the minimum tailwater which would be based on water-surface elevations in the upper pool of the Smithland Dam on the Ohio River. The minimum pool would be maintained with a control structure near the lower end of the Cumberland River and a navigation canal extending from the Cumberland River upstream of the control structure to the upper pool of Smithland Dam. The minimum tailwater el 324 would be based on normal upper pool of the Ohio River dam. Tailwater elevations at the lower end of the model used in the test of this plan were based on the results of a mathematical model established for the purpose. Tailwater elevations for the 120,000-cfs flow would not be affected and conditions would be the same as without the modification.

Results

36. Results of tests with the mathematical model indicated that with plan A the tailwater elevation at the lower end of the model (gage 8) would be from about 22.8 ft higher with one powerhouse unit in operation (10,250 cfs) to about 11.2 ft higher with the four units and 55,000-cfs discharge than that with existing conditions (Table 3). With the 80,000- and 100,000-cfs flows, the increase in tailwater elevation was about 5.8 to 2.6 ft, respectively. With the higher tailwater elevation, the differences in water-surface elevations between the end of

the lower guard wall and the end of the model (gages 2-8) were reduced considerably, particularly with the lower flows ranging from about 0.1 ft with the 10,250-cfs flow (one powerhouse unit) to about 1.6 ft with the 80,000-cfs flow. The difference with the 100,000-cfs flow was about 3.0 ft, about 0.9 ft less than that with existing conditions.

37. Current directions and velocities shown in Plates 23-28 indicate a considerable reduction in velocities, particularly during the lower flows compared with existing conditions. In the reach downstream of the dam and in the lock approach, there was some increase in the size of the eddy with one powerhouse unit in operation and a stronger eddy formed along the right bank just upstream of the highway bridge. Velocities of the upstream eddy currents along the left bank in the lock approach were somewhat higher with powerhouse unit 4 in operation than those with existing conditions. Current directions and alignment downstream of the lock approach were not affected appreciably by the higher tailwater elevation and there was little change in velocities with the 80,000- and 100,000-cfs flows.

38. Navigation conditions were generally about the same as those with existing conditions, particularly with flows of 55,000 cfs and higher. Conditions in the lower lock approach were about the same as those with existing conditions even with the lower flows because of the eddy currents and currents approaching the bridge just downstream. In the reach downstream, tows would have to maneuver with some flanking to negotiate the bends. Because of the reduction in velocities, less time would be required for upbound tows to navigate the reach reproduced in the model than with existing conditions. However, with the 55,000- and 80,000-cfs flows, the time required for upbound tows would be reduced only by about 2 to 4 percent, with practically no change for downbound tows because of the maneuvering required.

Plan B

39. Plan B was designed to improve navigation conditions in the

three sharp bends reproduced in the model. The plan involved widening of the bends and improving the alignment of the channel approaching the bends. The features of this plan shown in Figure 6 included the following:

- a. The left bank of the bend at mile 28.1 was excavated on a radius of 2,500 ft and tied in with the existing bank upstream and downstream. A fill to a top el 330 was placed along the right bank opposite the excavation to form a smooth curve in the bank line.
- b. The right bank of the bend at mile 25.6 was excavated on a radius of 2,800 ft and tied in with the existing bank upstream and downstream.
- c. The left bank of the bend at mile 24.5 was excavated on a radius of 3,100 ft and tied in with the existing bank upstream and downstream.

Tests of this plan were conducted with the tailwater elevations based on existing conditions. All excavations were to el 290 which would provide a depth of 12 ft with existing minimum tailwater elevation.

Results

40. Results shown in Table 4 indicate some lowering in the water-surface elevations except with the 10,250-cfs flow which was not affected appreciably. Most of the lowering in water-surface elevation occurred in the reach downstream of Hwy 62 and 641 Bridge (gage 3) and varied from about 0.5 to 1.0 ft with flows of 40,320 to 120,000 cfs. The drop in water-surface elevation from the end of the lower guard wall (gages 2-8) varied from about 1.1 ft with the 10,250-cfs flow to about 3.4 ft with the 80,000-cfs flow. With this condition, the maximum average slope would be about 0.5 ft/mile.

41. Current directions and velocities shown in Plates 29-34 indicate little change in the alignment of the currents through the reach. Because of the lowering of the water-surface elevations, velocities were somewhat higher than those with existing conditions except with the 10,250-cfs flow. Maximum velocities approaching Hwy 62 and 641 Bridge were increased with all of the higher flows ranging from about 5.9 fps with the 40,320-cfs flow to about 8.3 fps with the 80,000-cfs flow. The maximum velocities in the bends were generally less than

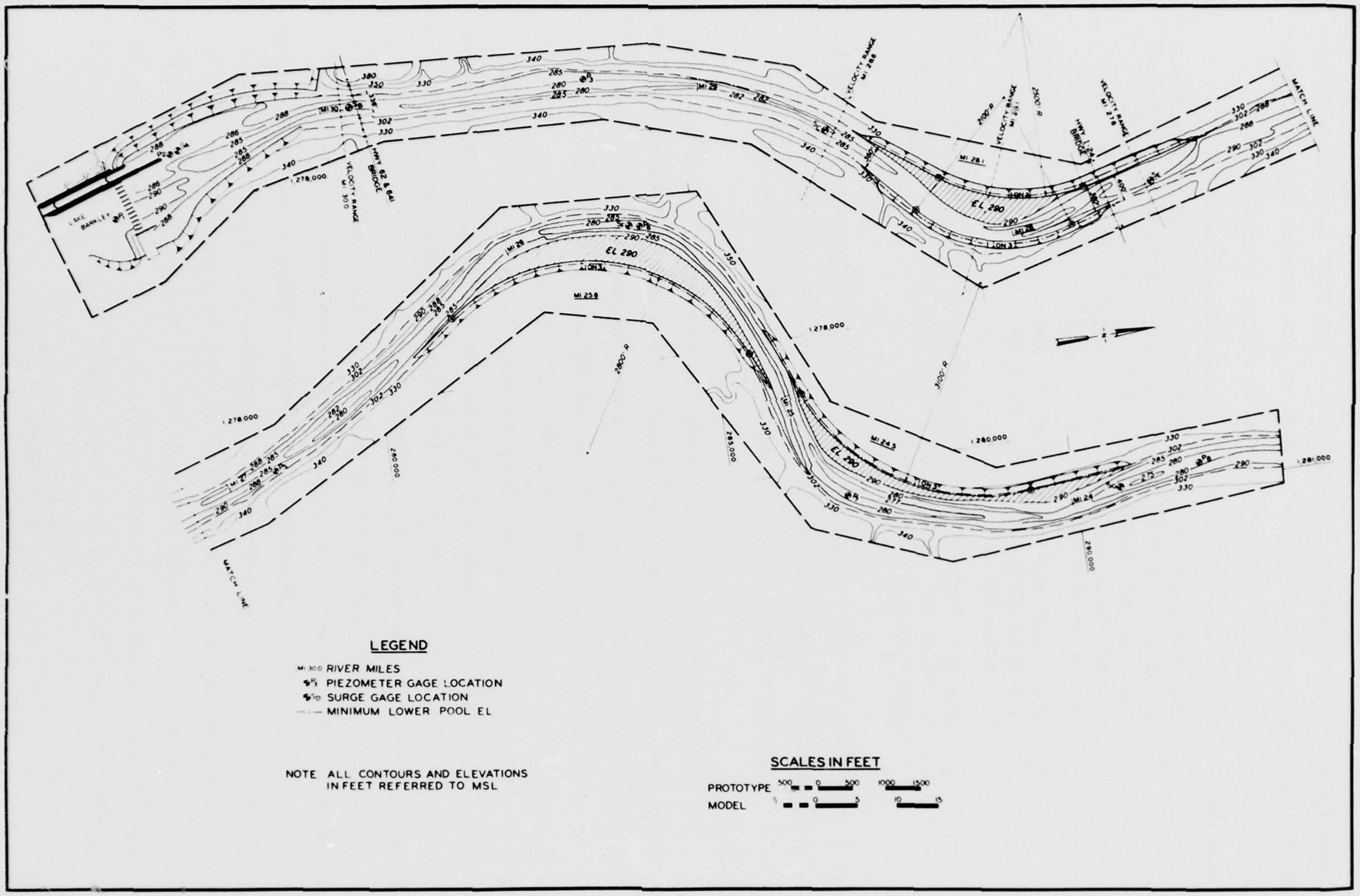


Figure 6. Plan B

those with existing conditions except in the bend near range 30 where maximum velocities were as much as 9.6 fps with the 120,000-cfs flow.

42. Navigation conditions in the lower lock approach were about the same as those with existing conditions because of the eddy and alignment of currents in the approach. Navigation conditions through the reach below the lock approach were considerably better than those with existing conditions; and downbound tows could navigate the bends without flanking, provided the bends were approached from along the convex bank in each bend. Navigation conditions for downbound tows approaching the Hwy I-24 Bridge could be hazardous with flows greater than 55,000 cfs because of the tendency for tows to be moved from along the left bank toward the right bank soon after entering the bend. The tendency would increase as the tows moved through the bend, and downbound tows could be in danger of hitting the right bank or the right pier of the bridge navigation span. Upbound tows should experience no serious difficulties in navigating the reach. Upbound tows could navigate the reach about 13 to 18 percent faster than with existing conditions with flows of 55,000 and 80,000 cfs. With those flows, elimination of the need for flanking would reduce by about 34 percent time required for downbound tows to negotiate the reach compared with existing conditions.

Plan B-Modified

Description

43. Plan B-modified was the same as plan B except for modifications designed to improve conditions for downbound tows approaching the Hwy I-24 Bridge. The modification shown in Figure 7 involved the removal of the fill along the right bank and construction of a longitudinal dike along the bank with its downstream end placed slightly riverward of the bridge pier on the right of the navigation span. The top of the dike was at el 330 with side slopes of 1V on 3H.

Results

44. Modifications of plan B had little or no effect on

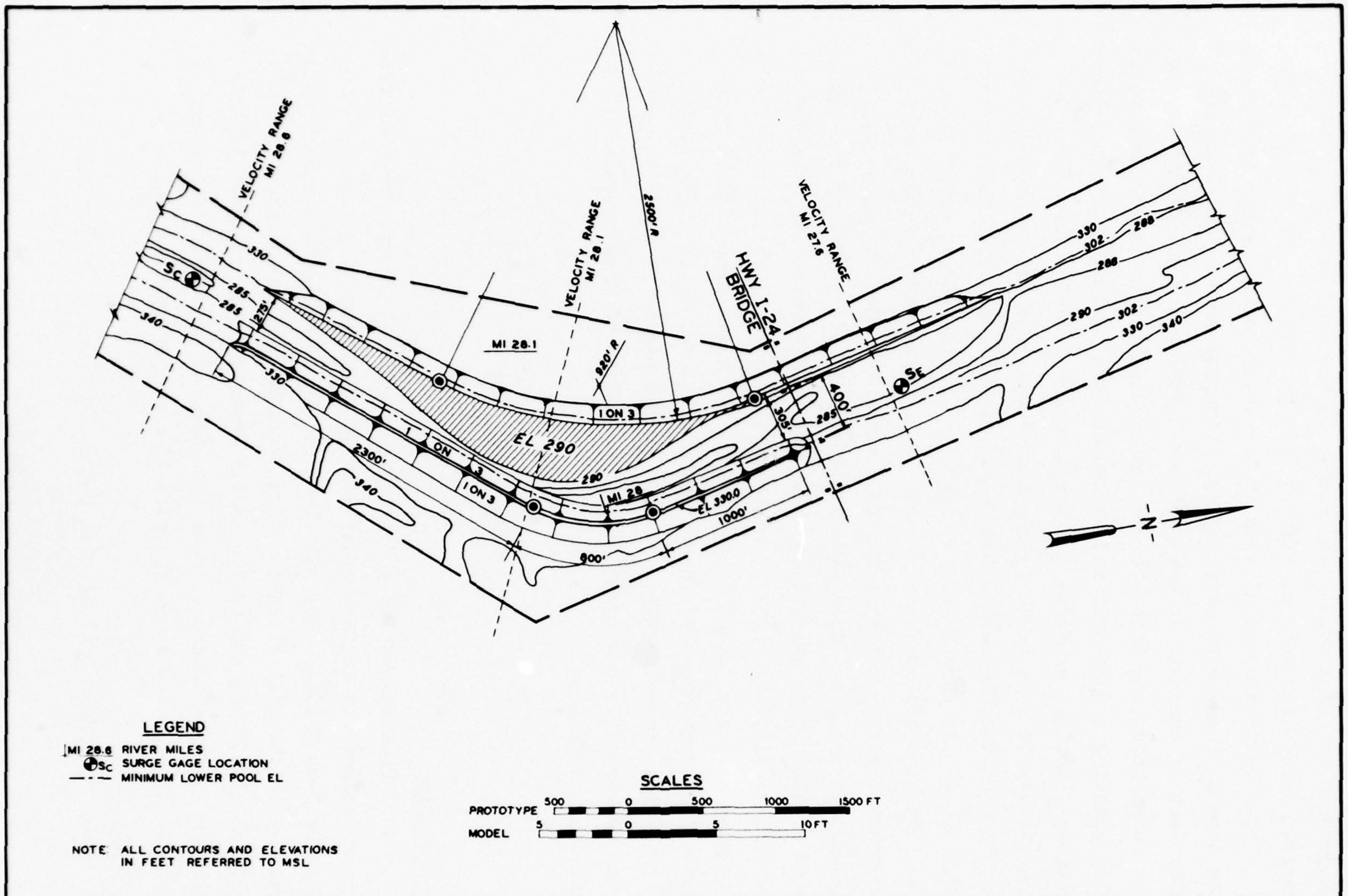


Figure 7. Plan B-modified

water-surface elevations (Table 5). Results shown in Plate 35 indicate some increase in velocities through the modified bend but the alignment of currents was somewhat better. Currents continued to move from the left bank at the upper end of the bend toward the right bank, which would tend to move a downbound tow toward the dike. Downbound tows could be moved against the dike but would not be in danger of hitting the bridge pier since the dike would be slightly riverward of the pier. Navigation conditions were not affected for upbound tows and the times required to navigate the reach in both directions were about the same as those with plan B.

Plan C

Description

45. Plan C was the same as plan B-modified (Figure 7) except that the minimum water-surface elevations near the Ohio River would be maintained at el 308. This was based on the use of a control structure near the lower end of the Cumberland River and a lock constructed in a canal extending from the Cumberland River upstream of the control structure to the upper pool of Smithland Dam. Tailwater elevations for the lower reach of the physical model with this condition were based on the results developed by the mathematical model. These results indicated that flows above 80,000 cfs would not be affected by the plan.

Results

46. Results shown in Table 6 indicate that the tailwater elevation (gage 8) would be from about 9.7 to about 4.5 ft higher than with existing conditions with flows of 10,250 to 55,000 cfs, respectively. The difference in water-surface elevations from the lower end of the lock guard wall to the end of the model (gages 2-8) varied from about 0.5 ft with the 10,250-cfs flow to about 3.0 ft with the 80,000-cfs flow.

47. Current directions and velocities indicate that there would be some reduction in velocities approaching the Hwy 62 and 641 Bridge with the 10,250-cfs flow with little change in the alignment and velocity of currents in the lower lock approach compared with existing

conditions (Plates 36 and 37). There was also little change in the alignment of currents downstream of the lock approach except in the three bends which had been modified (Plates 38-40, Photos 12-14). The maximum velocities in the bends and straight reaches were reduced with the 40,320- and 55,000-cfs flows and varied from about 4.0 to 5.3 fps near range 15, 5.5 to 6.1 fps near range 30, 3.0 to 4.1 fps near range 57, and 4.4 to 5.5 fps in the bend near range 69. Maximum velocities in the bends were somewhat higher with the 80,000-cfs flow ranging between 7.7 and 8.9 fps except in the bend near range 57 which was reduced to about 5.4 fps.

48. Navigation conditions in the reach were generally about the same as those with plan B-modified except for some reduction in the time required to navigate the reach, particularly with upbound tows and flows of about 55,000 cfs (Photos 15-21). The reach could be negotiated by downbound tows about 36 and 34 percent faster than with existing conditions with flows of 55,000 and 80,000 cfs, respectively. Upbound tows could navigate the reach about 25 and 21 percent faster with the two flows, respectively.

Plan C-Modified

Description

49. Plan C-modified was the same as plan C except for the addition of the 600-ft-long dike along the right side of the lock approach and the dike forming an extension of the wall between the powerhouse and spillway as shown in Figure 5 (existing conditions-modified).

Results

50. Water-surface elevations with the modifications were about the same as those with plan C (Table 7). Results shown in Plates 41-44 and Photo 22 indicate that a large eddy would continue to form in the lower lock approach with flow through the powerhouse only. The alignment of the currents along the left bank resulting from the eddy were considerably better than that with plan C, particularly with one powerhouse unit in operation. Also, the alignment of currents moving toward

the left bank downstream of the eddy was better and not as abrupt as that with plan C. The size of the eddy in the lower lock approach decreased with flow through the spillway. Conditions with the powerhouse units in operation were not as good as with the existing conditions-modified because of the size and intensity of the eddy in the lock approach attributed to the higher water-surface elevation which overtopped the dikes. Currents approaching the Hwy 62 and 641 Bridge were affected by the eddy that formed along the right bank upstream of the bridge with one powerhouse unit in operation.

51. Navigation conditions in the lower lock approach were considerably better than those with plan C because of the improvement in the alignment of the currents (Photo 23). However, conditions with this plan were not as good as with the existing condition-modified plan. The tendency for tows to be moved toward and against the left bank in the approach was practically eliminated. Tows would tend to be moved toward the left bank and the left pier of the navigation span of the bridge by currents just downstream of the lower dike. This tendency can be offset without serious difficulty by approaching the bridge from the center of the channel. Navigation conditions downstream of the Hwy 62 and 641 Bridge were not affected by the dikes included in the modification.

PART IV: DISCUSSION OF RESULTS AND CONCLUSIONS

Limitation of Model Results

52. Analysis of the results of this investigation is based on a study of the effects of various plans and modifications on water-surface elevations, current directions and velocities, and the effects of the resulting currents on the behavior of the model towboat and tow. In evaluating test results, it should be considered that small changes in current directions and velocities are not necessarily changes produced by a modification in plan since several floats introduced at the same point may follow a different path and move at somewhat different velocities because of pulsating currents and eddies. Current directions and velocities shown in the plates were obtained with floats submerged to a depth of a loaded barge (9 ft prototype) and are more indicative of the currents that would affect the behavior of tows than those indicated by photographs which indicate the movement of confetti on the water surface and are affected by surface tension.

53. The small scale of the model made it difficult to reproduce accurately the hydraulic characteristics of the prototype structures or to measure water-surface elevations within an accuracy greater than about ± 0.1 ft prototype. Also, current directions and velocities were based on steady flows and would be somewhat different with varying flows, particularly with rapid changes in powerhouse discharge. The model was of the fixed-bed type and was not designed to reproduce any sediment movement that might occur in the prototype; therefore changes in channel configurations resulting from scouring and deposition could not be developed naturally.

Summary of Results and Conclusions

54. The following results and conclusions were developed during the investigation:

<u>a</u>. Navigation conditions with existing conditions are

difficult and hazardous, particularly for large tows, and are affected by changes in powerhouse discharges, eddy currents in the lower lock approach, narrow channel and sharp bends, and the alignment and velocity of currents approaching the bridges and bends.

b. The rate of change in water-surface elevation increases with a decrease in the time interval that the individual powerhouse units are placed in or removed from operation. The rate of change decreases with the distance downstream of the dam.

c. Navigation conditions in the lower lock approach and through the Hwy 62 and 641 Bridge could be improved considerably with dikes that formed an extension of the wall between the powerhouse and spillway and in the channel downstream of the end of the lower guard wall with existing tailwater (Figure 5). The dikes would not be nearly as effective with the high tailwater tested, since the dikes would be overtopped even with one powerhouse unit in operation. Dikes with top elevation higher than 303 were not tested.

d. An increase in the tailwater elevation without other changes would reduce velocities, particularly during the lower flows, but would not eliminate the maneuvering required by large tows in negotiating the sharp bends and in approaching the lock. Most of the navigation improvement with the higher tailwater would occur during the lower flows when no powerhouse units are in operation and when only one or two units are in operation because of the increase in depth and lower velocities.

e. Widening the channel in the sharp bends and realignment of the banks in the approaches to the bends produced the most improvement in navigation conditions of the plans tested. With modification of the bends and existing tailwater conditions, downbound tows could navigate the reach about 34 percent faster than with existing conditions with flows of 55,000 and 80,000 cfs. Upbound tows could navigate the reach about 13 and 18 percent faster with the flows mentioned.

f. Raising of the tailwater elevation with the modified bends would have little effect on time required for downbound tows to negotiate the reach, but upbound tows could navigate the reach about 25 percent faster than with existing conditions with the 55,000-cfs flow and about 21 percent faster with the 80,000-cfs flow.

g. Raising of the tailwater elevation would reduce the rate and amount of change in water-surface elevation with changes in powerhouse units in operation; however, with

higher tailwater elevation, the head available for power would be reduced substantially.

h. Modification of the bends as tested would tend to reduce the tailwater elevation at the powerhouse except with the lower flows (one unit in operation) and increase the head available for power.

i. The higher tailwater elevations as tested would have little effect on navigation conditions in the lower lock approach.

Table 1

Existing Conditions

Gage No.	Water-Surface Elevations, ft msl Q, cfs 10,250	Q, cfs 20,500	Q, cfs 40,320	Q, cfs 55,000	Q, cfs 55,000	Q, cfs 80,000	Q, cfs 100,000	Q, cfs 120,000
1	359.0	359.0	359.0	359.0	359.0	359.0	359.0	359.0
2	302.5*	305.8*	313.9	317.3	319.7	324.9	329.1	336.7
3	302.3	305.5	313.6	317.1	319.5	324.3	328.4	336.1
4	302.1	304.6	312.9	316.3	318.8	323.3	327.5	335.3
5	301.8	304.1	312.3	315.7	318.3	322.6	326.9	334.9
6	301.6	303.8	311.8	315.4	317.8	322.0	326.3	334.3
7	301.4	303.4	311.1	314.7	317.5	321.2	325.7	334.1
8	301.3	302.6	310.7**	314.1**	317.1**	320.7**	325.2**	333.6**

* Controlled elevations based on prototype records.

** Controlled elevations based on Ohio River data and extended upstream to the lower end of the model reach by means of the mathematical model.

Table 2

Existing Conditions-Modified

Gage No.	Water-Surface Elevations, ft msl Q, cfs 10,250	Q, cfs 55,000	Q, cfs 80,000	Q, cfs 100,000	Q, cfs 120,000
1	359.0	359.0	359.0	359.0	359.0
2	302.5	317.3	324.9	329.1	336.7
3	302.3	317.1	324.3	328.4	336.1
4	302.1	316.3	323.3	327.5	335.3
5	301.8	315.7	322.6	326.9	334.9
6	301.6	315.4	322.0	326.3	334.3
7	301.4	314.7	321.2	325.7	334.1
8	301.3*	314.1*	320.7*	325.2*	333.6*

* Controlled elevations same as those developed with existing conditions.

Table 3

Plan A

Gage No.	Water-Surface Elevations, ft msl Q, cfs 10,250	Q, cfs 40,320	Q, cfs 55,000	Q, cfs 80,000	Q, cfs 100,000
1	359.0	359.0	359.0	359.0	359.0
2	324.2	325.5	326.5	328.1	330.8
3	324.2	325.5	326.5	328.1	330.5
4	324.2	325.3	326.3	328.0	329.7
5	324.1	325.2	326.1	327.8	329.1
6	324.1	325.0	325.9	327.2	328.8
7	324.1	325.0	325.8	326.8	328.4
8	324.1*	324.7*	325.3*	326.5*	327.8*

* Controlled elevations developed with mathematical model assuming a controlled minimum tailwater el 324.0 near the Ohio River.

Table 4

Plan B

Gage No.	Water-Surface Elevations, ft msl Q, cfs 10,250	Q, cfs 40,320	Q, cfs 55,000	Q, cfs 80,000	Q, cfs 100,000	Q, cfs 120,000
1	359.0	359.0	359.0	359.0	359.0	359.0
2	302.4	313.3	317.0	324.1	328.4	336.1
3	302.4	312.9	316.6	323.5	327.4	335.6
4	302.2	312.5	316.1	322.8	327.3	335.1
5	301.8	311.6	315.5	321.9	326.3	334.6
6	301.5	311.3	314.7	321.5	326.2	334.1
7	301.4	311.0	314.6	321.2	325.7	334.0
8	301.3*	310.7*	314.1*	320.7*	325.2*	333.6*

* Controlled elevations same as those with existing conditions.

Table 5

Plan B-Modified

Gage No.	Water-Surface Elevations, ft msl Q, cfs 55,000	Q, cfs 80,000	Q, cfs 120,000
1	359.0	359.0	359.0
2	317.0	324.1	336.1
3	316.6	323.5	335.6
4	316.1	322.8	335.1
5	315.5	321.9	334.6
6	314.7	321.5	334.1
7	314.6	321.2	334.0
8	314.1*	320.7*	333.6*

* Controlled elevations same as those with existing conditions.

Table 6

Plan C

Gage No.	Water-Surface Elevations, ft msl Q, cfs 10,250	Q, cfs 40,320	Q, cfs 55,000	Q, cfs 80,000
1	359.0	359.0	359.0	359.0
2	311.5	317.9	320.7	324.6
3	311.5	317.9	320.6	324.2
4	311.3	317.5	320.2	323.7
5	311.1	317.1	319.5	322.7
6	311.0	317.0	319.4	322.6
7	311.0	316.9	319.2	322.2
8	311.0*	316.5*	318.6*	321.6*

* Controlled elevations developed with mathematical model assuming a controlled minimum tailwater el 308.0 near the Ohio River.

Table 7

Plan C-Modified

Gage No.	Water-Surface Elevations, ft msl Q, cfs 10,250	Q, cfs 55,000	Q, cfs 80,000
1	359.0	359.0	359.0
2	311.5	320.7	324.6
3	311.5	320.6	324.2
4	311.3	320.2	323.7
5	311.1	319.5	322.7
6	311.0	319.4	322.6
7	311.0	319.2	322.2
8	311.0*	318.6*	321.6*

* Controlled elevations same as those with plan C.

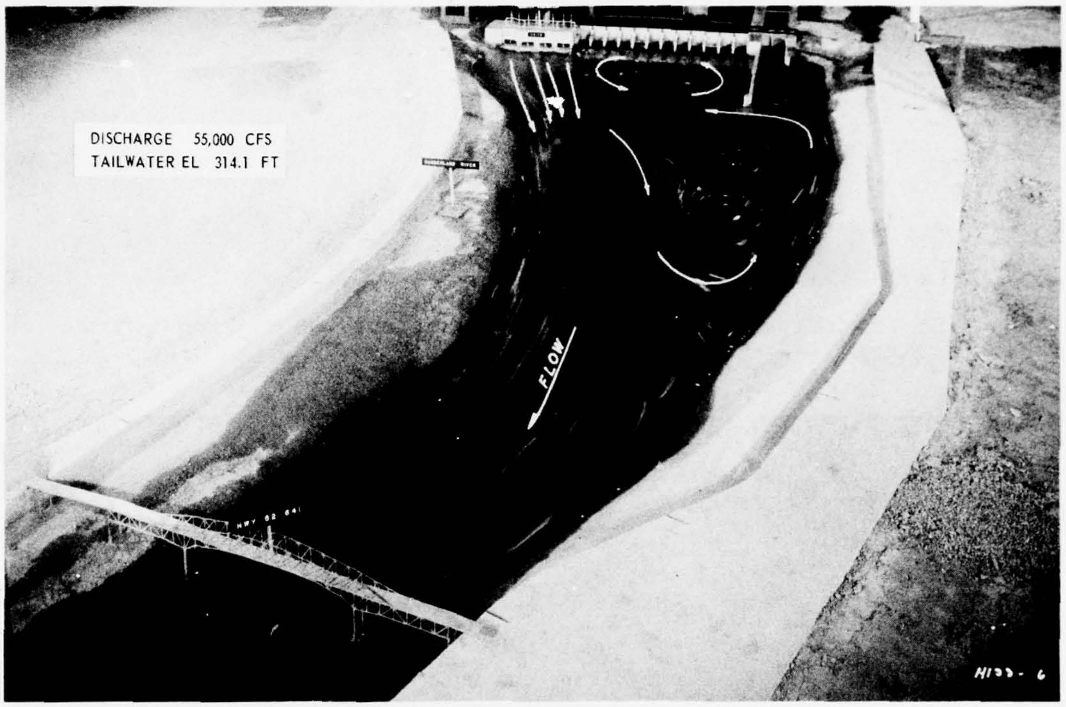


Photo 1. Existing conditions; surface currents in lower lock approach with all flow through powerhouse

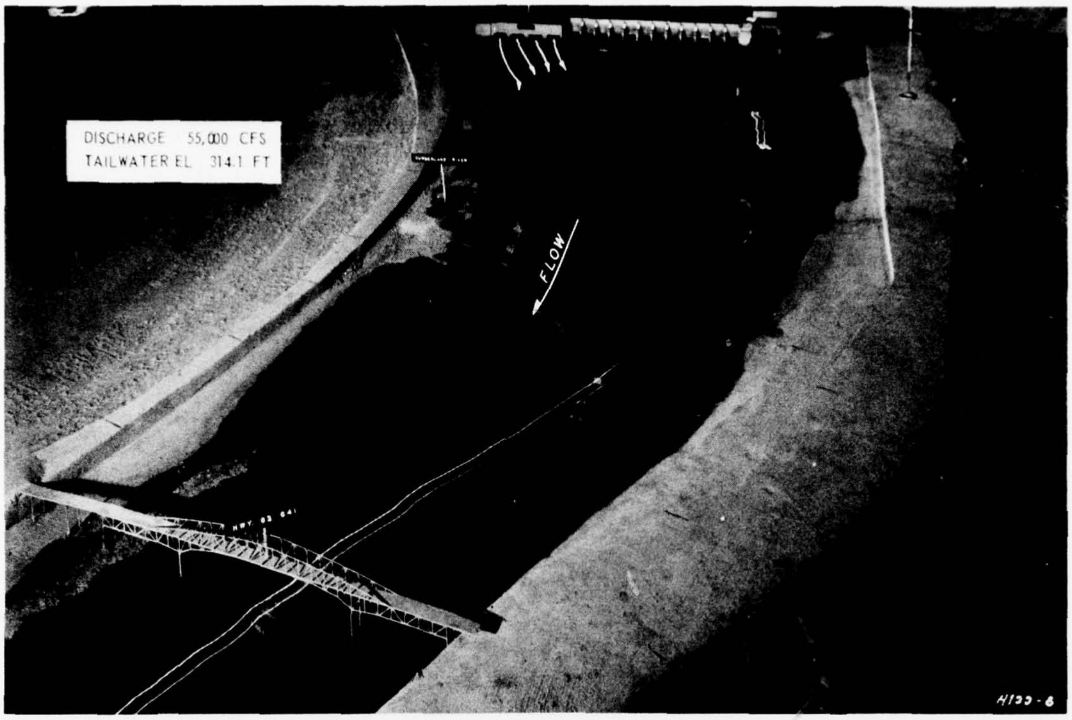


Photo 2. Existing conditions; path of upbound tow passing through bridge downstream of the dam and approaching the lock

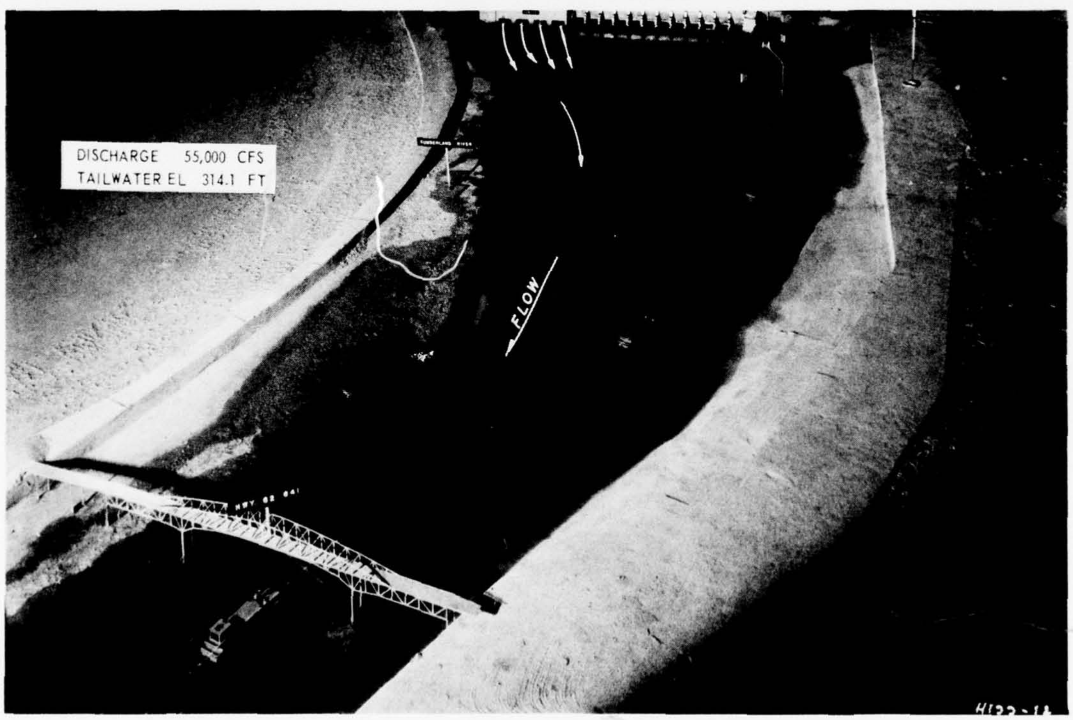


Photo 3. Existing conditions; path of downbound tow passing through the bridge after leaving lock. Note tendency for tow to be moved toward left bank after leaving the lock

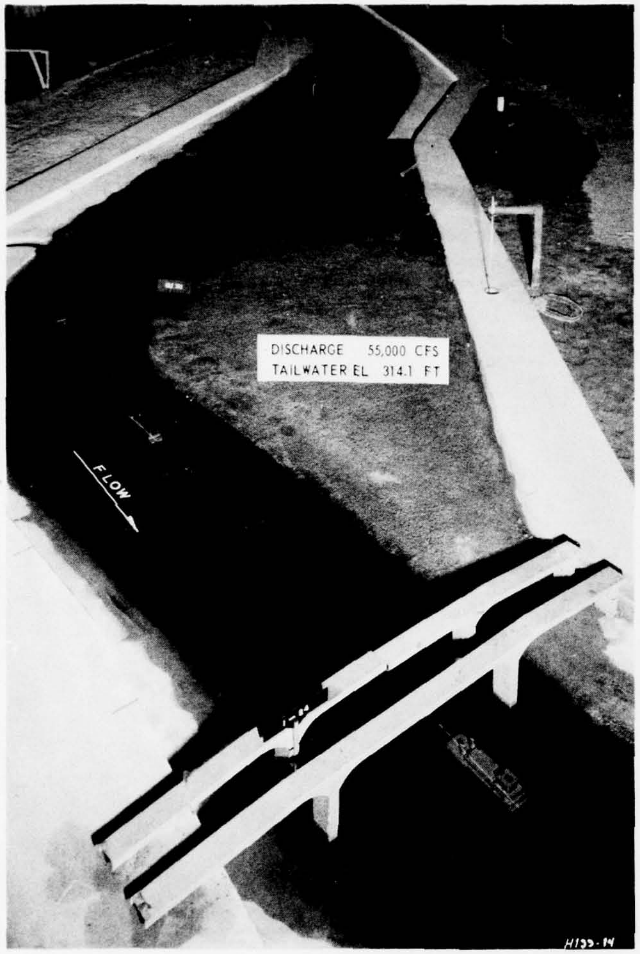


Photo 4. Existing conditions; path of downbound tow flanking in the bend at mile 28.1 and passing Hwy I-24 Bridge

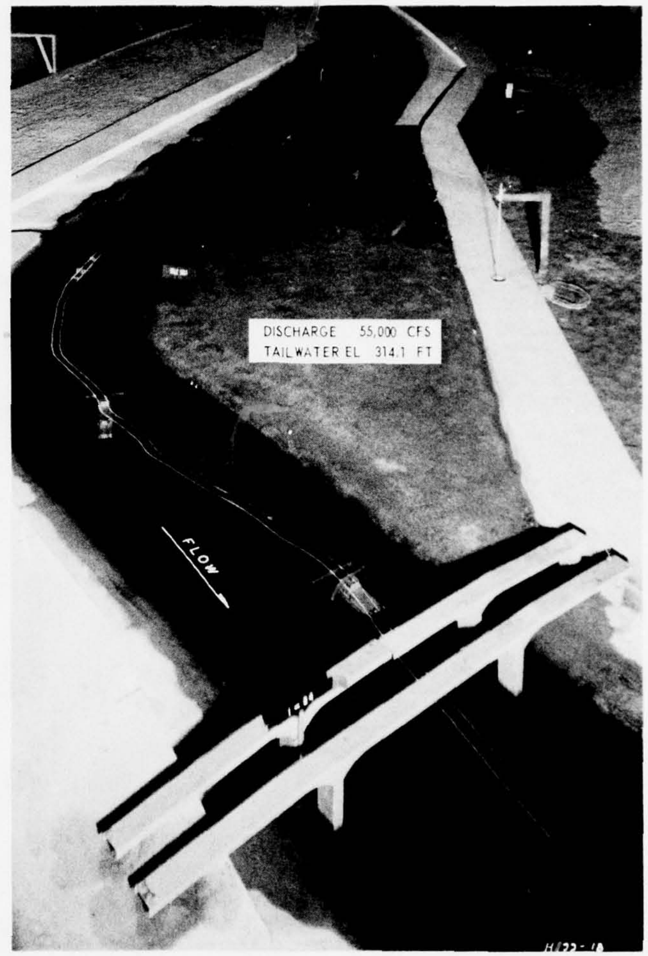


Photo 5. Existing conditions; path of upbound tow passing Hwy I-24 Bridge and through the bend at mile 28.1

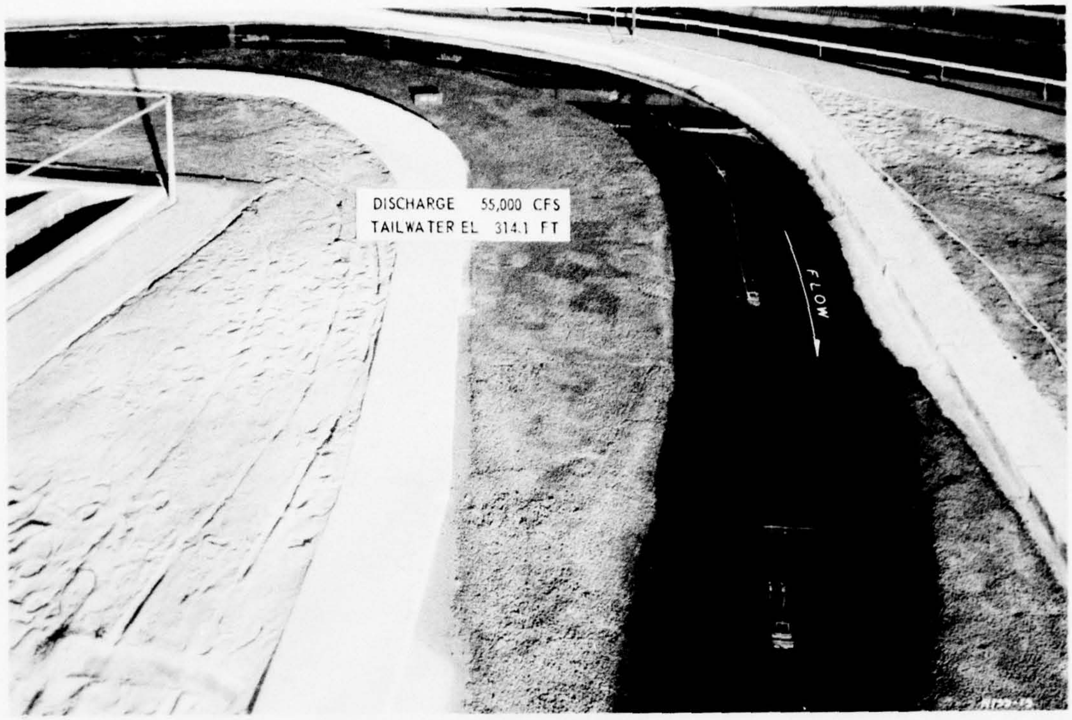


Photo 6. Existing conditions; path of downbound tow flanking the bend at mile 25.6

Photo 7. Existing conditions; path of upbound tow driving the bend at mile 25.6

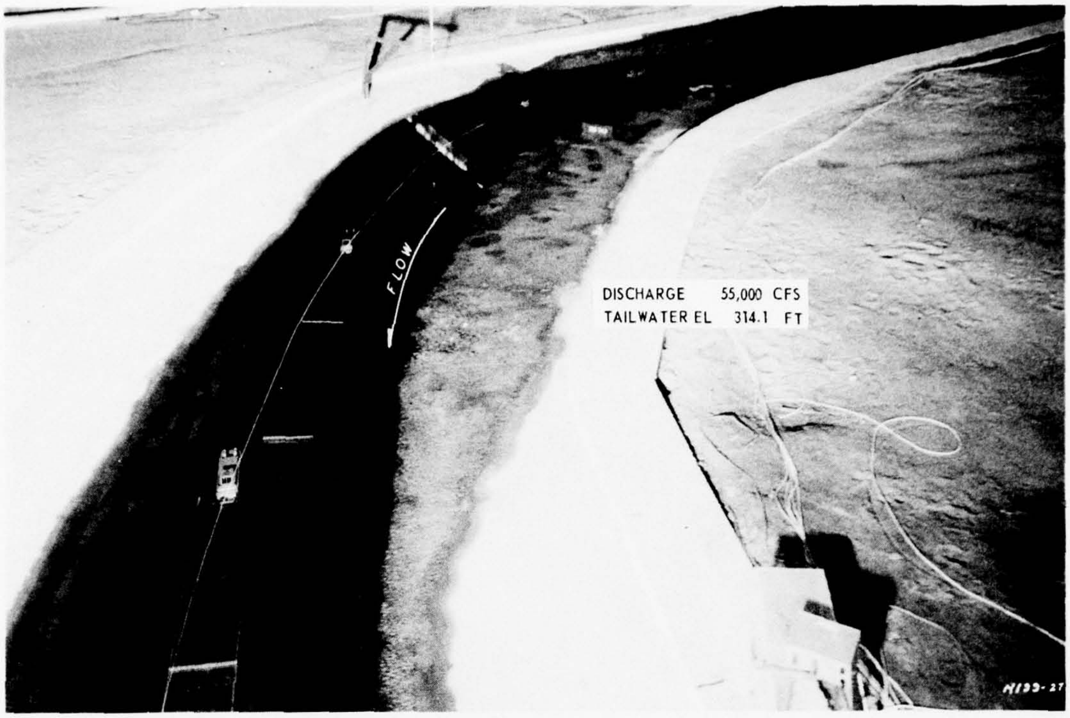
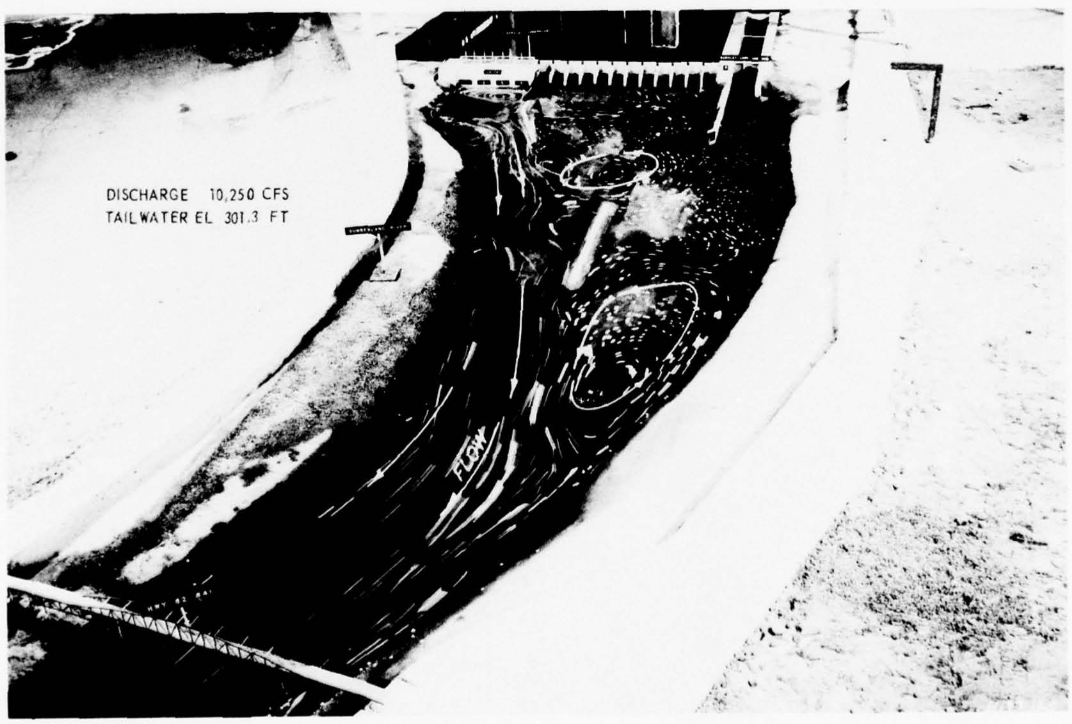


Photo 8. Existing conditions; path of downbound tow flanking the bend at mile 24.5

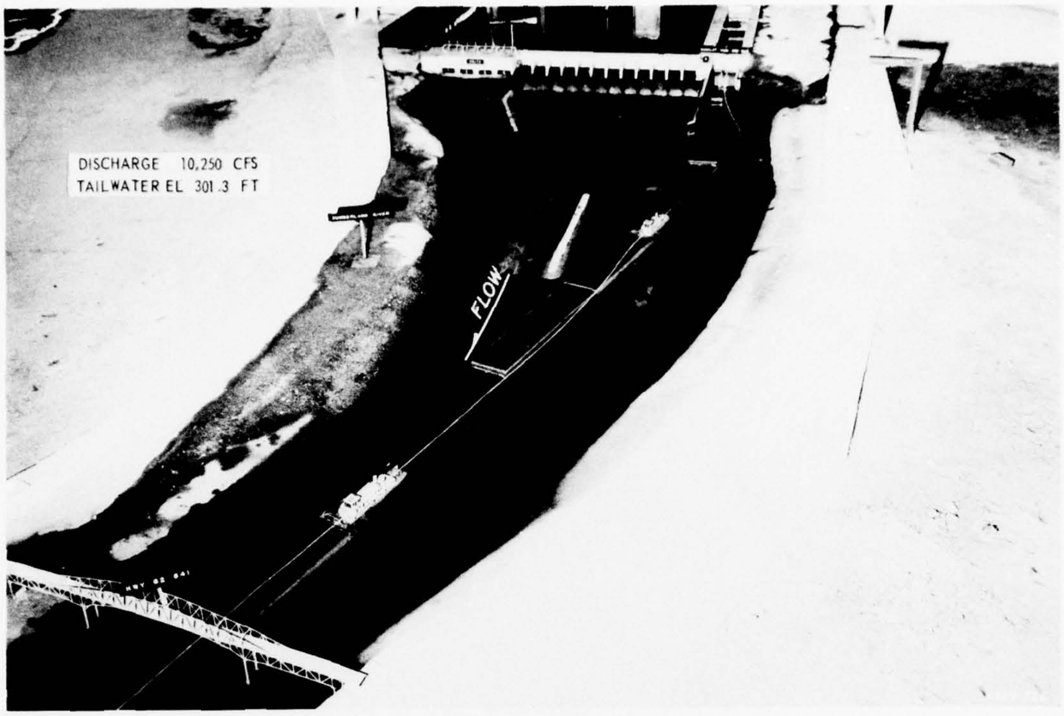
Photo 9. Existing conditions; path of upbound tow negotiating the bend at mile 24.5

a. Dye showing current pattern in lock approach

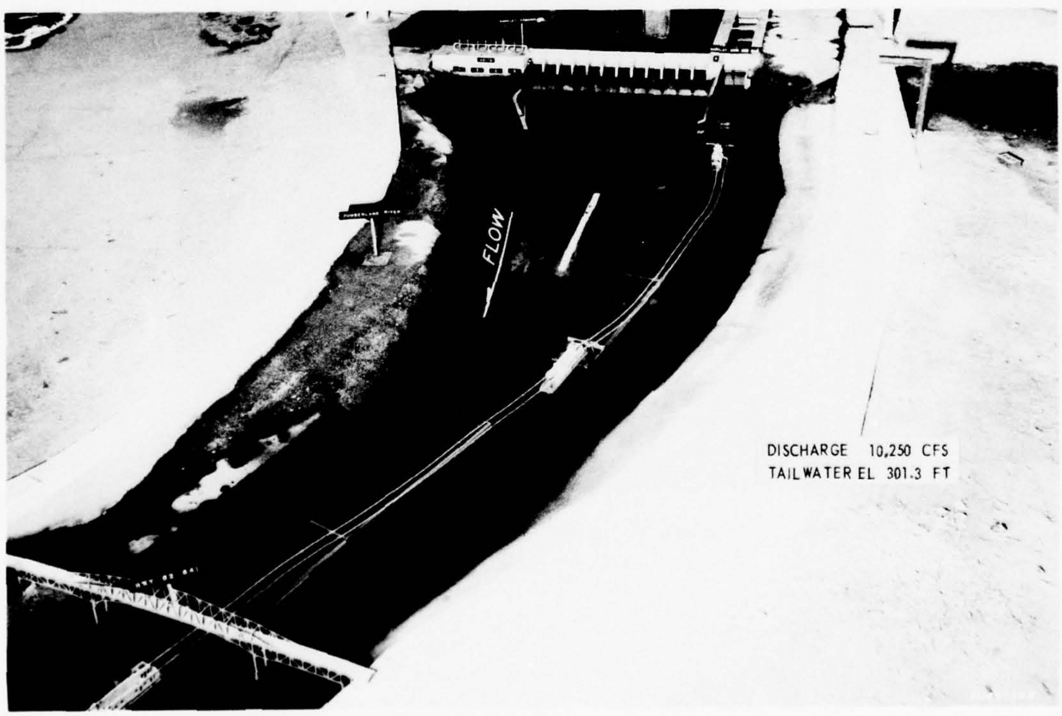


b. Confetti showing surface currents in lock approach

Photo 10. Existing conditions-modified; powerhouse unit 1 in operation, current patterns



a. Downbound tow leaving lock and approaching bridge



b. Upbound tow passing through bridge and approaching the lock

Photo 11. Existing conditions-modified; powerhouse unit 1 in operation, typical paths of tows

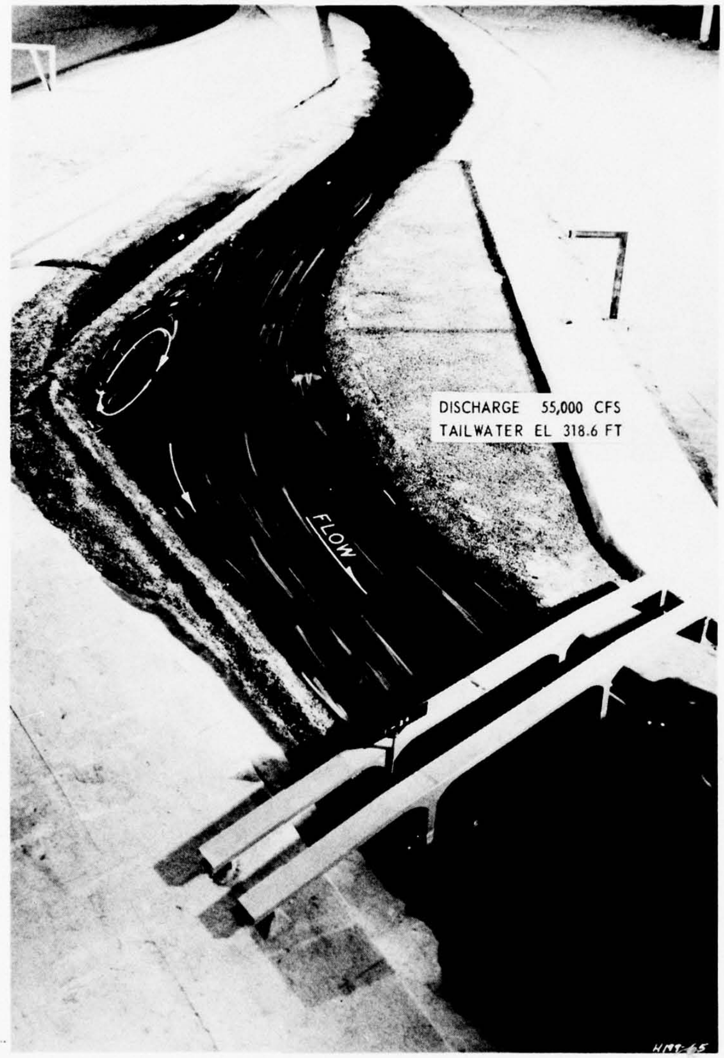


Photo 12. Plan C; surface currents through the bend at mile 28.1

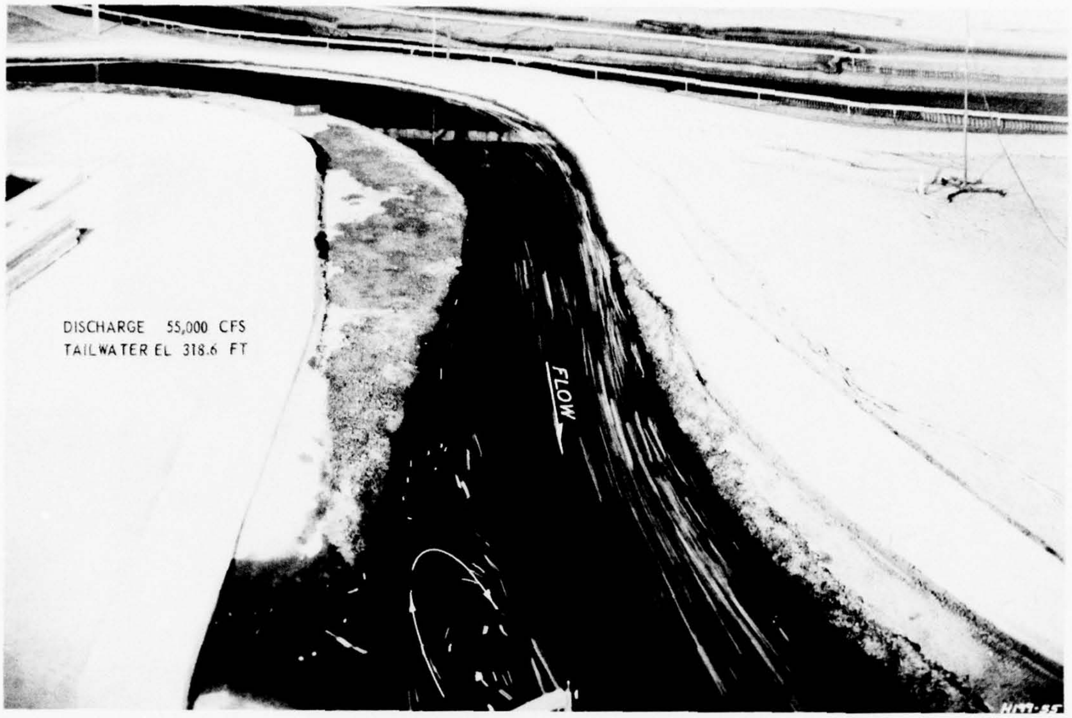


Photo 13. Plan C; surface currents approaching and through the bend at mile 25.6

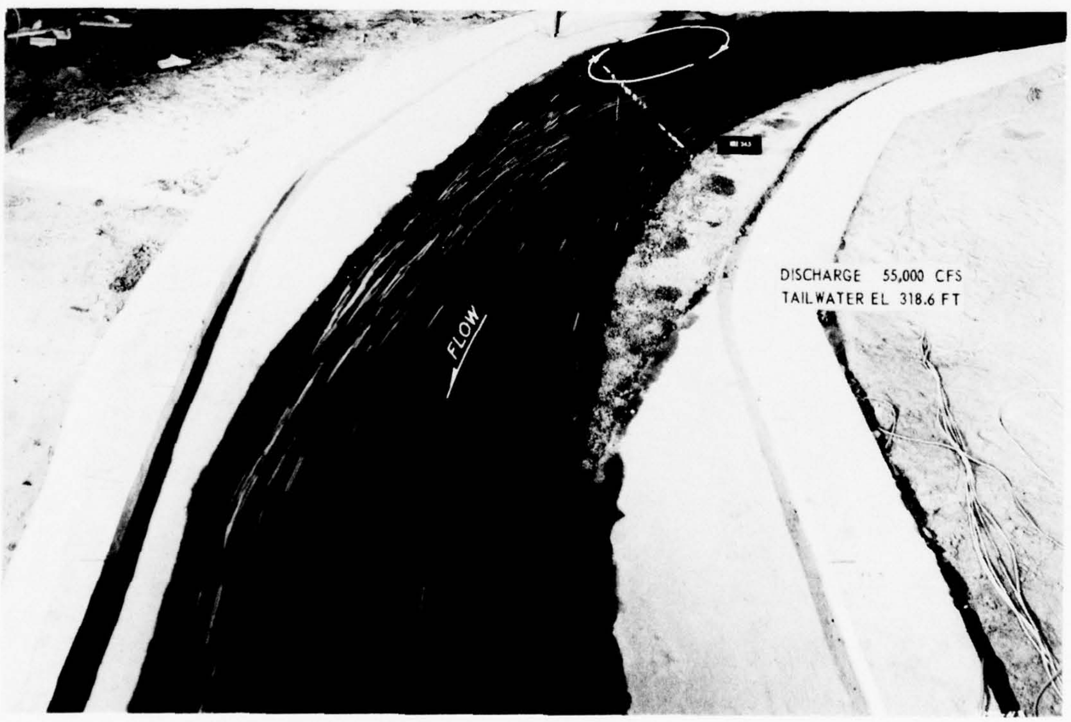


Photo 14. Plan C; surface currents through the bend at mile 24.5

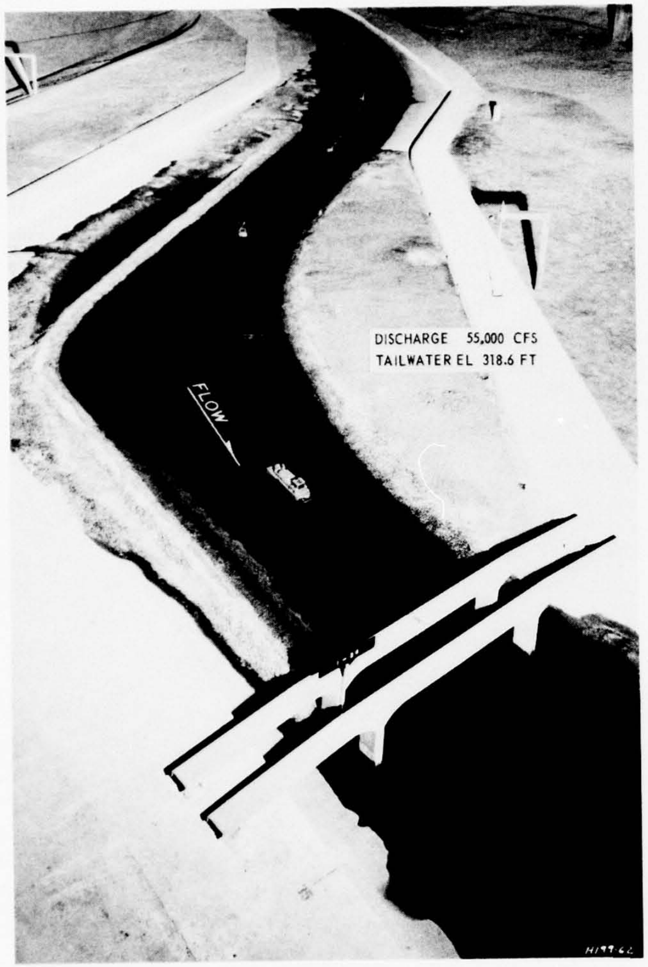


Photo 15. Plan C; path of downbound tow navigating bend at mile 28.1 and through the Hwy I-24 Bridge

Photo 16. Plan C; path of downbound tow navigating bend at mile 28.1. Note tendency for tow to be moved toward the right pier of the bridge span

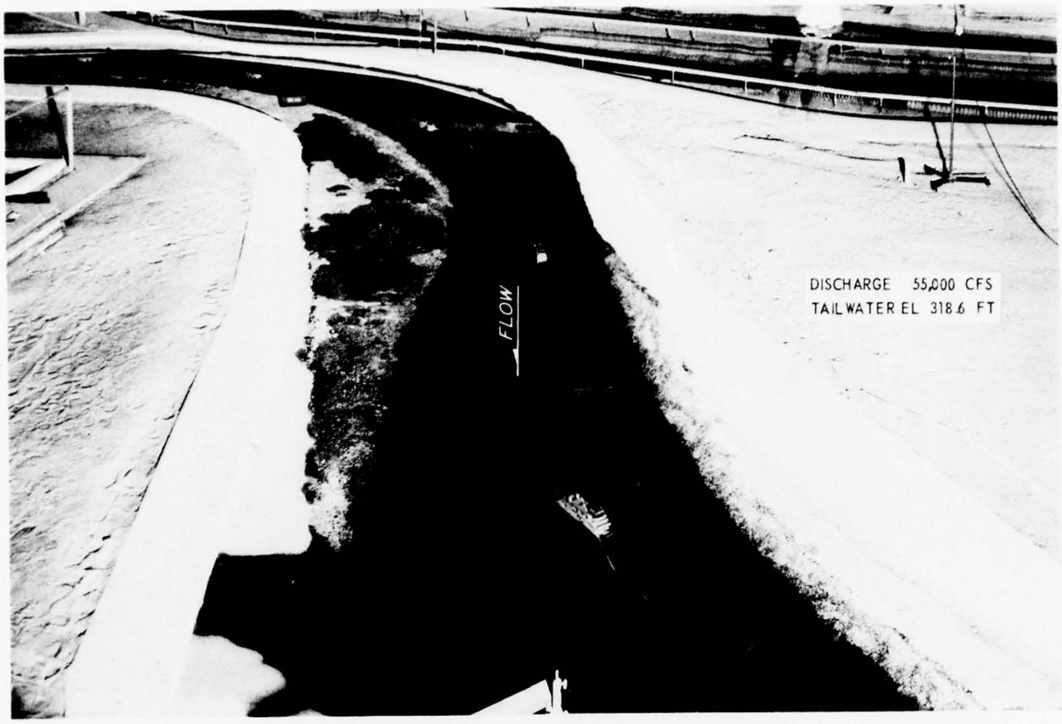


Photo 17. Plan C; path of downbound tow navigating through bend at mile 25.6

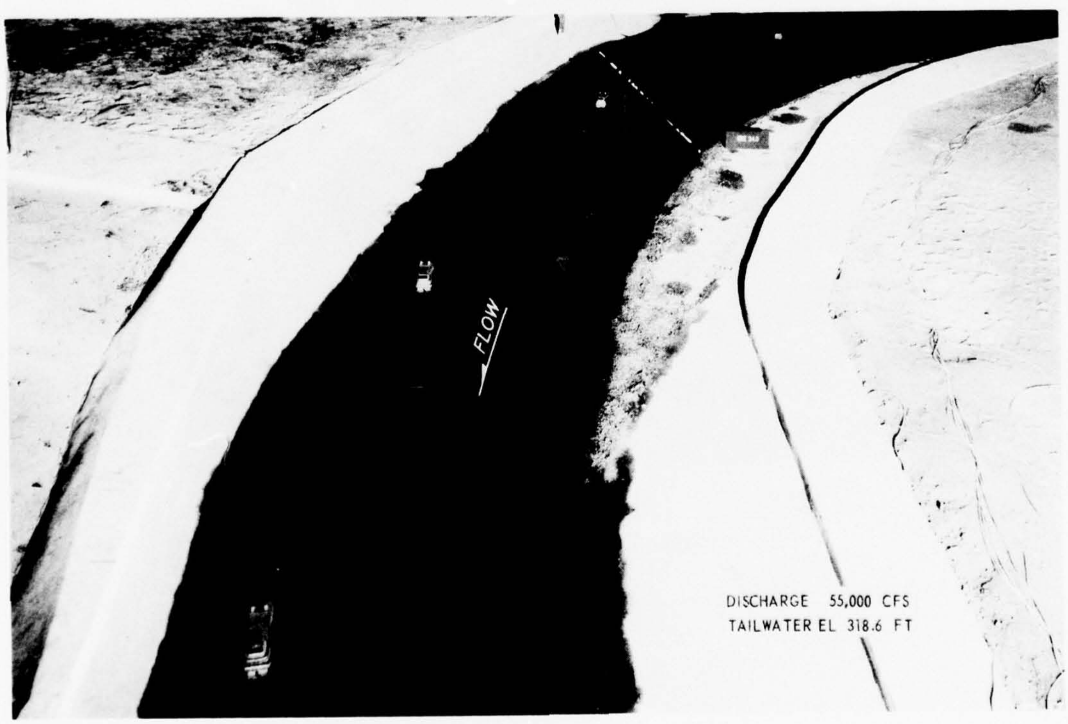


Photo 18. Plan C; path of downbound tow navigating through bend at mile 24.5

Photo 19. Plan C; path of upbound tow navigating bend at mile 28.1

Photo 20. Plan C; path of upbound tow navigating bend at mile 25.6

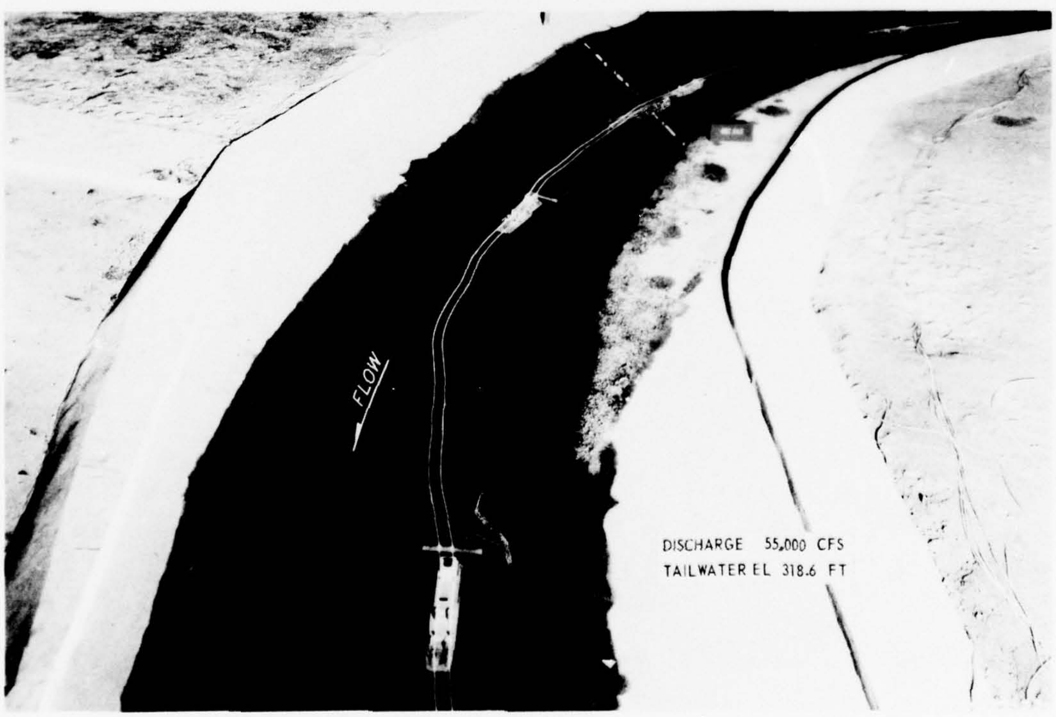
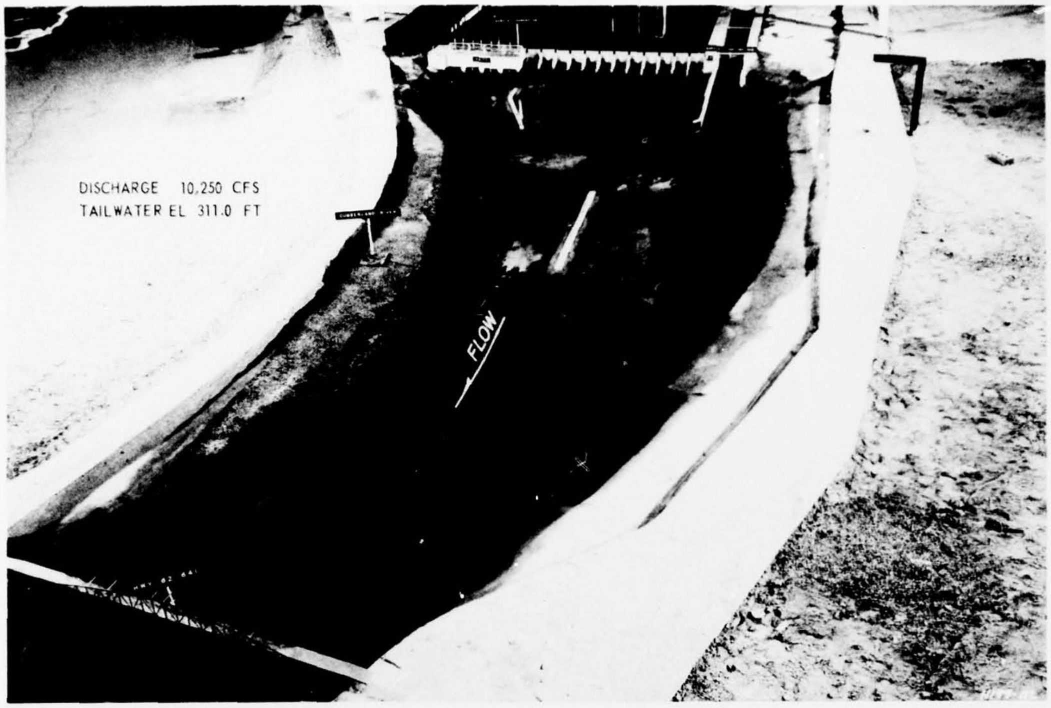
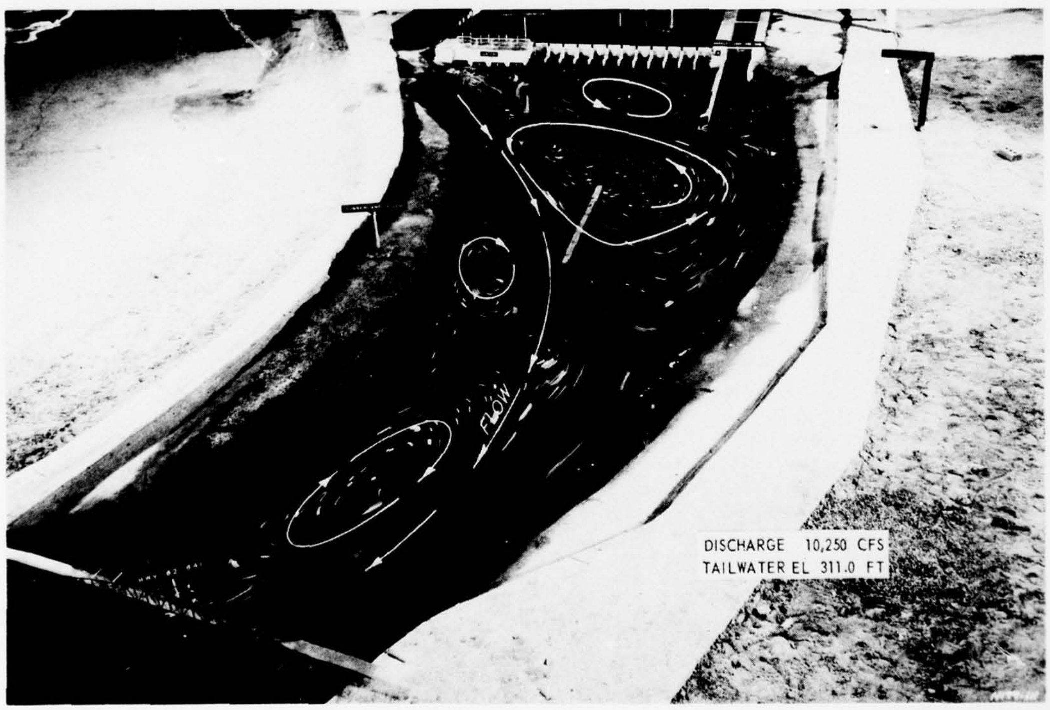


Photo 21. Plan C; path of upbound tow navigating bend at mile 24.5

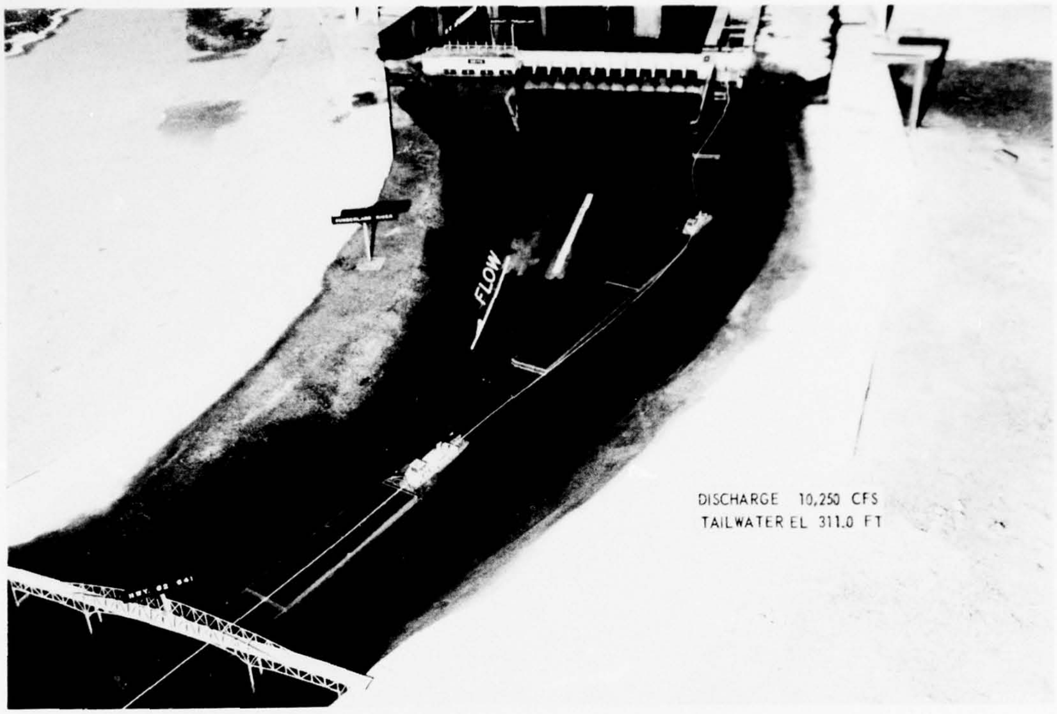


a. Dye showing current pattern in lock approach

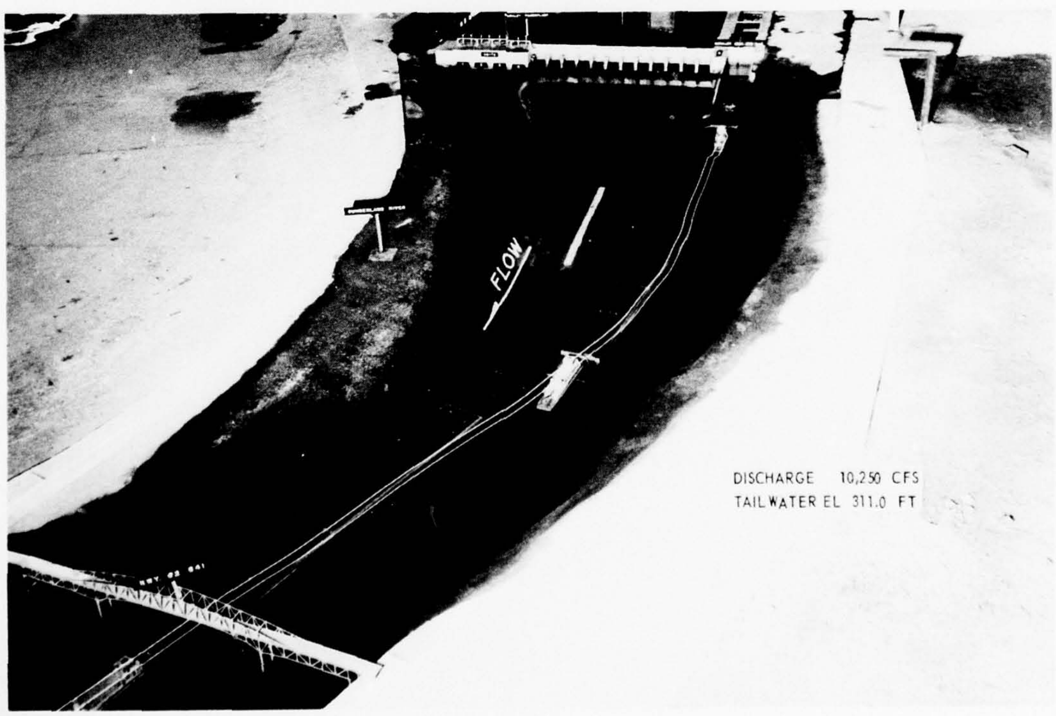


b. Confetti showing surface currents in lock approach

Photo 22. Plan C-modified; powerhouse unit 1 in operation, current patterns

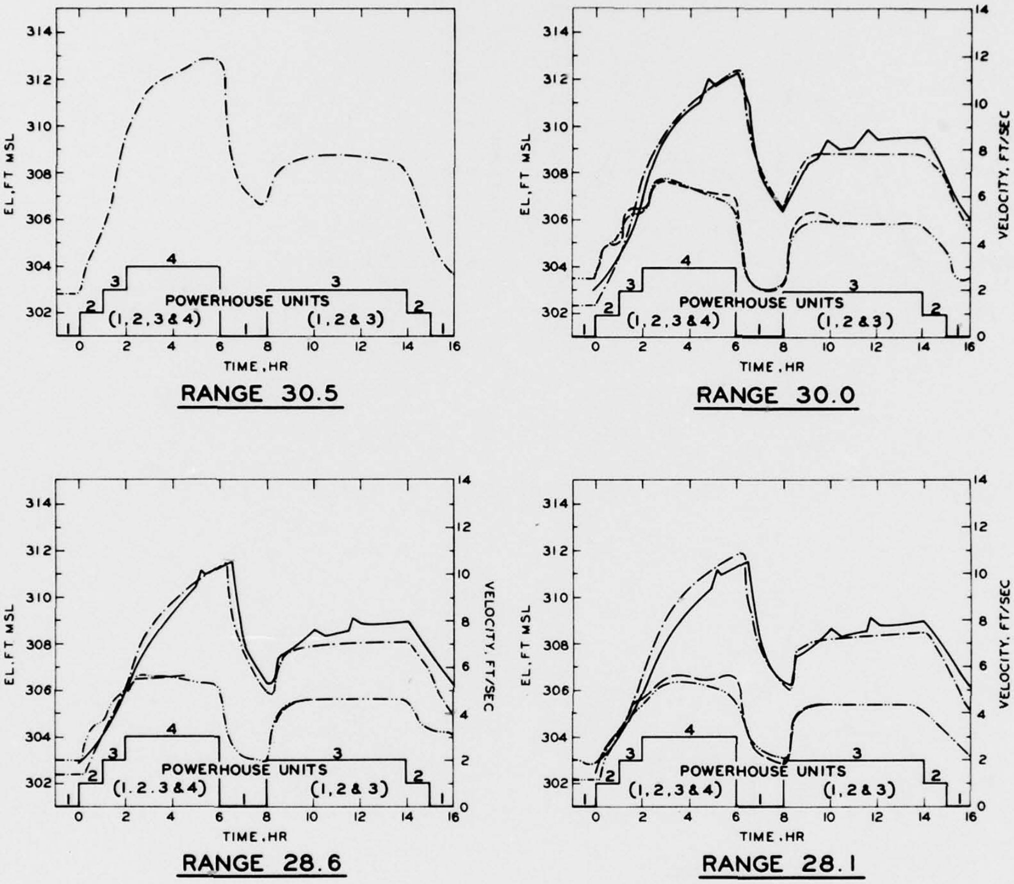


a. Downbound tow in the reach downstream of the lock



b. Upbound tow approaching the lock

Photo 23. Plan C-modified; powerhouse unit 1 in operation, typical paths of tows



LEGEND

ELEVATION, VELOCITY — PROTOTYPE

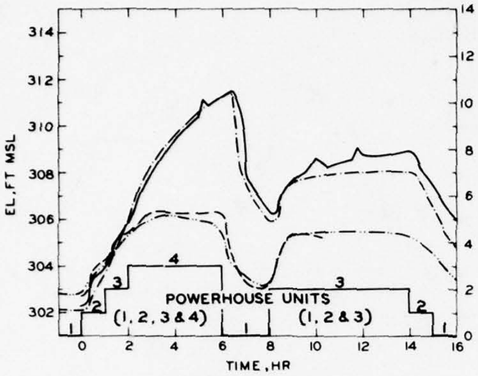
ELEVATION, VELOCITY — MODEL

POWERHOUSE SURGES

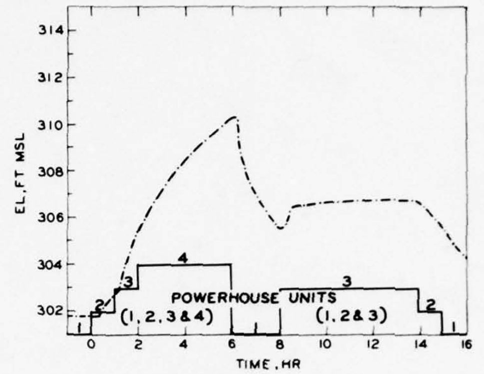
BASE TEST

HYDROGRAPH 1

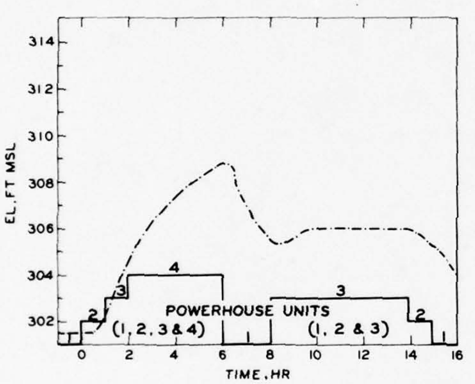
RANGES 30.5, 30.0, 28.6, AND 28.1



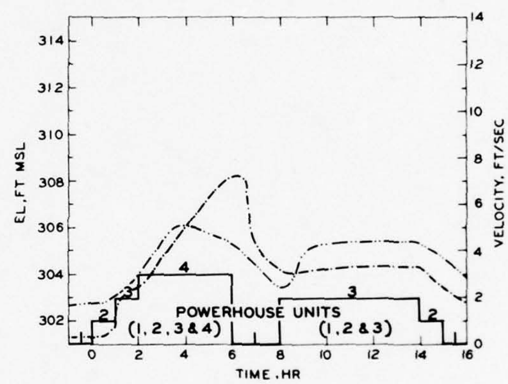
RANGE 27.6



RANGE 25.6



RANGE 24.5



RANGE 23.8

LEGEND

——— ELEVATION, ------- VELOCITY } PROTOTYPE

— — — ELEVATION, — — — VELOCITY } MODEL

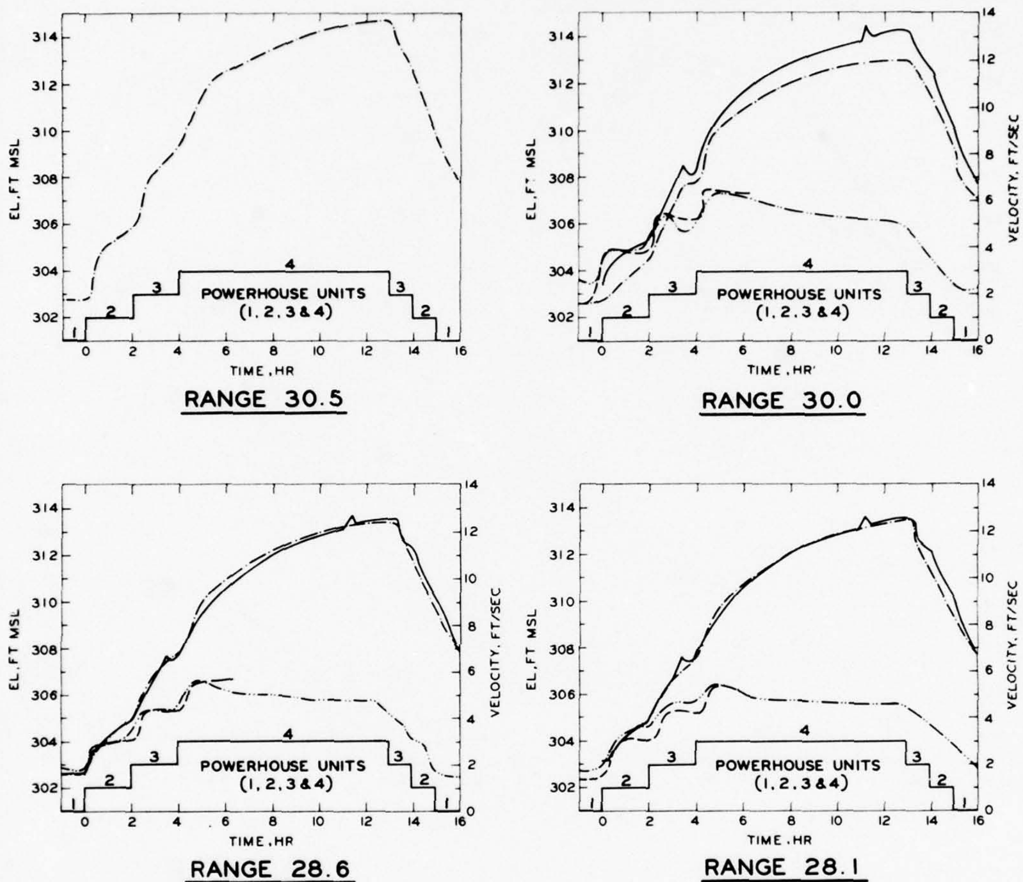
POWERHOUSE SURGES

BASE TEST

HYDROGRAPH 1

RANGES 27.6, 25.6, 24.5, AND 23.8

PLATE 2



LEGEND

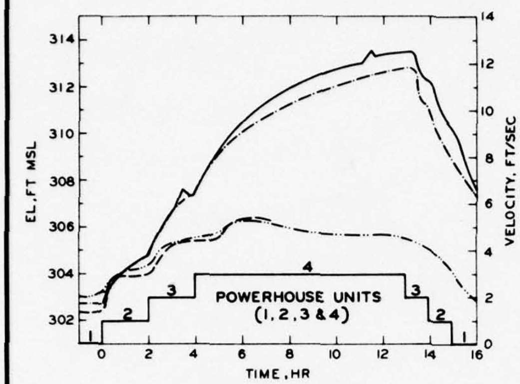
ELEVATION	} PROTOTYPE	
VELOCITY		
ELEVATION	} MODEL	
VELOCITY		

POWERHOUSE SURGES

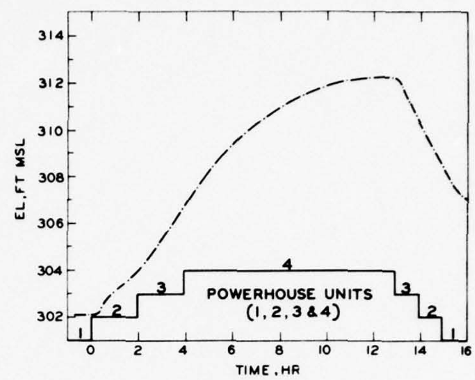
BASE TEST

HYDROGRAPH 2

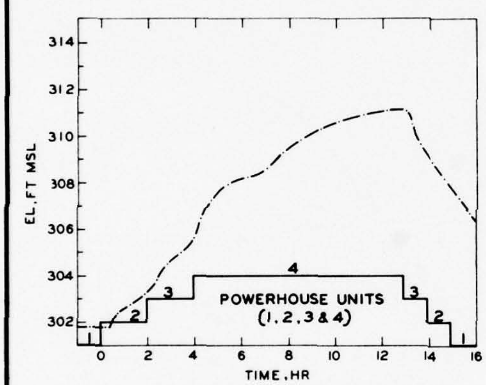
RANGES 30.5, 30.0, 28.6, AND 28.1



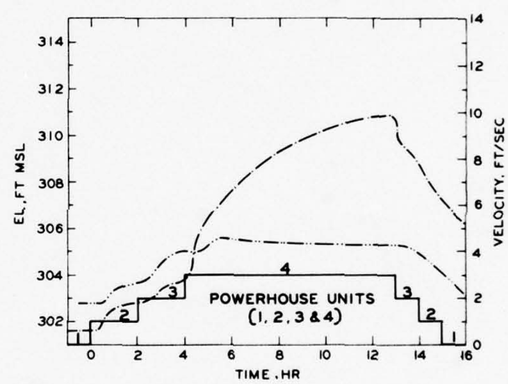
RANGE 27.6



RANGE 25.6



RANGE 24.5



RANGE 23.8

LEGEND

ELEVATION } PROTOTYPE
VELOCITY

ELEVATION } MODEL
VELOCITY

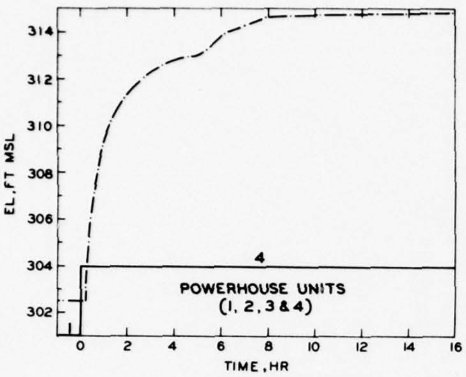
POWERHOUSE SURGES

BASE TEST

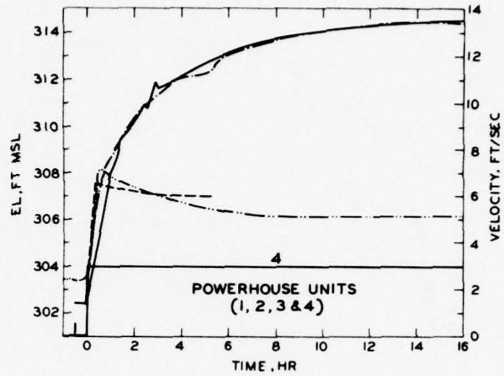
HYDROGRAPH 2

RANGES 27.6, 25.6, 24.5, AND 23.8

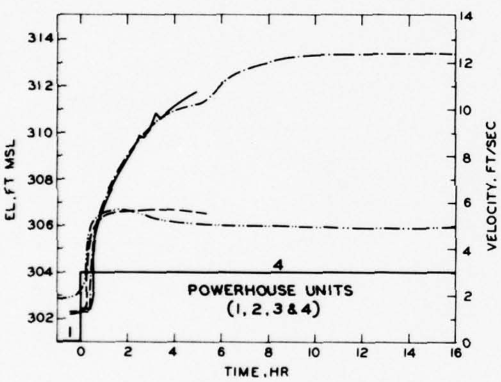
PLATE 4



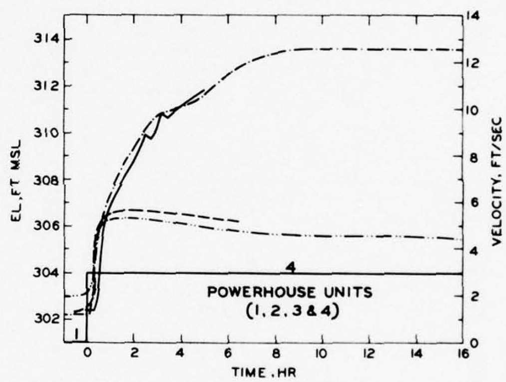
RANGE 30.5



RANGE 30.0



RANGE 28.6



RANGE 28.1

LEGEND

ELEVATION, VELOCITY } PROTOTYPE

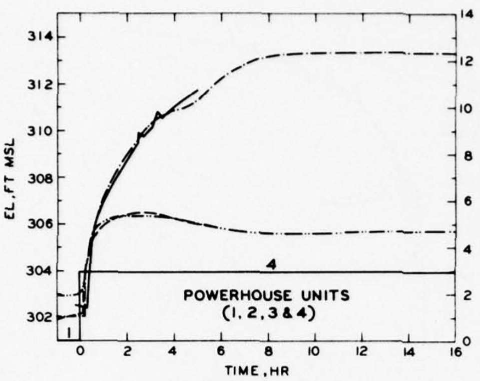
ELEVATION, VELOCITY } MODEL

POWERHOUSE SURGES

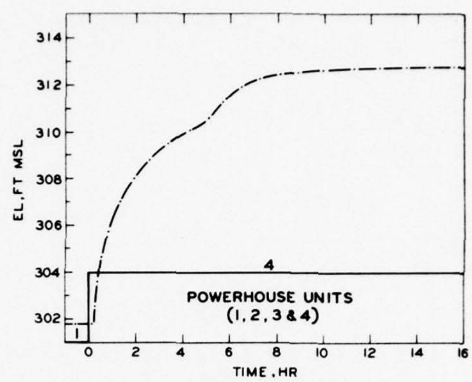
BASE TEST

HYDROGRAPH 3

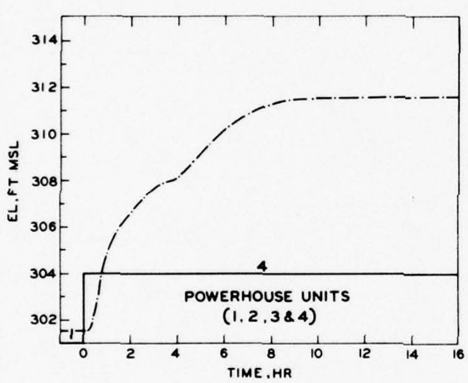
RANGES 30.5, 30.0, 28.6, AND 28.1



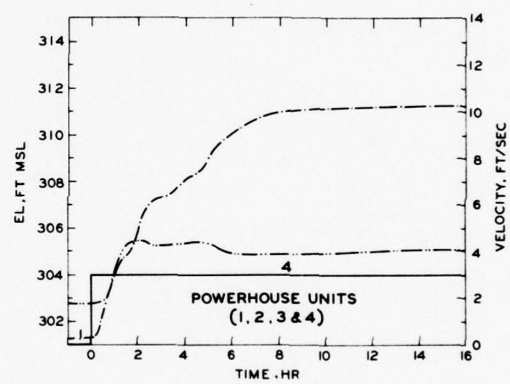
RANGE 27.6



RANGE 25.6



RANGE 24.5



RANGE 23.8

LEGEND

ELEVATION } PROTOTYPE
VELOCITY

ELEVATION } MODEL
VELOCITY

POWERHOUSE SURGES
BASE TEST
HYDROGRAPH 3
RANGES 27.6, 25.6, 24.5, AND 23.8

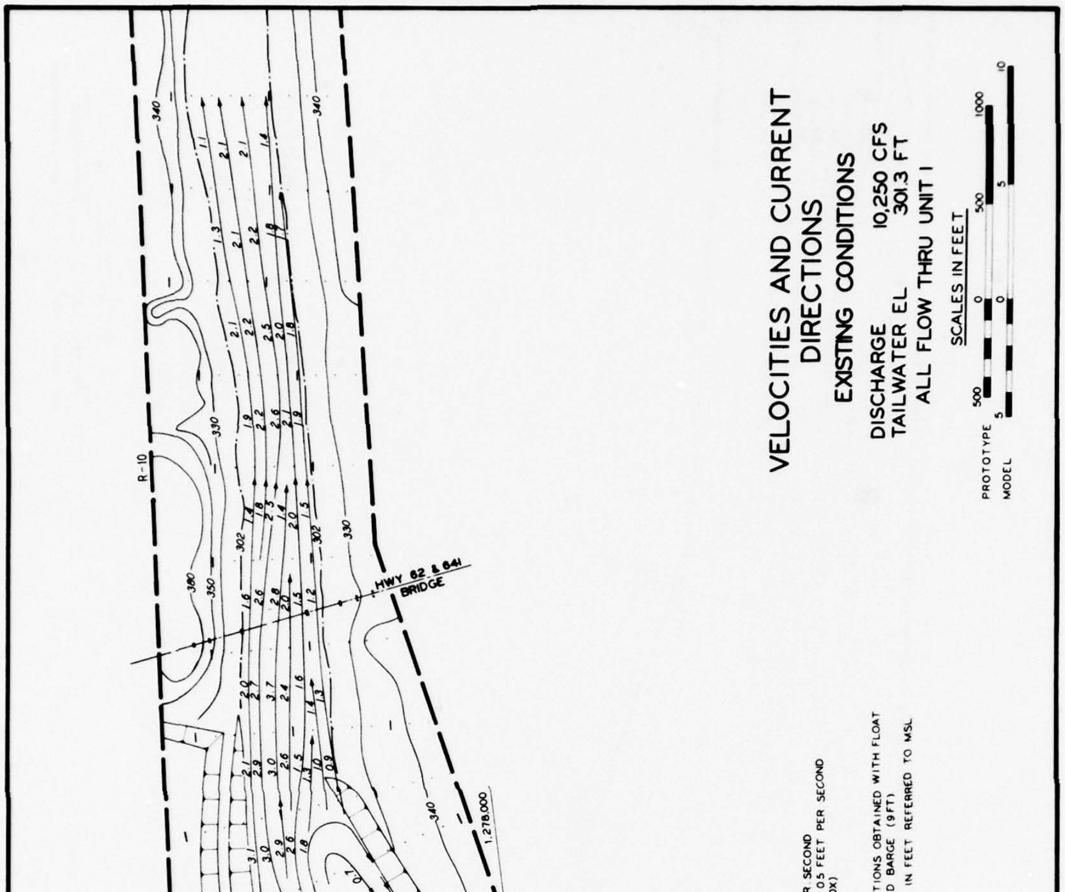
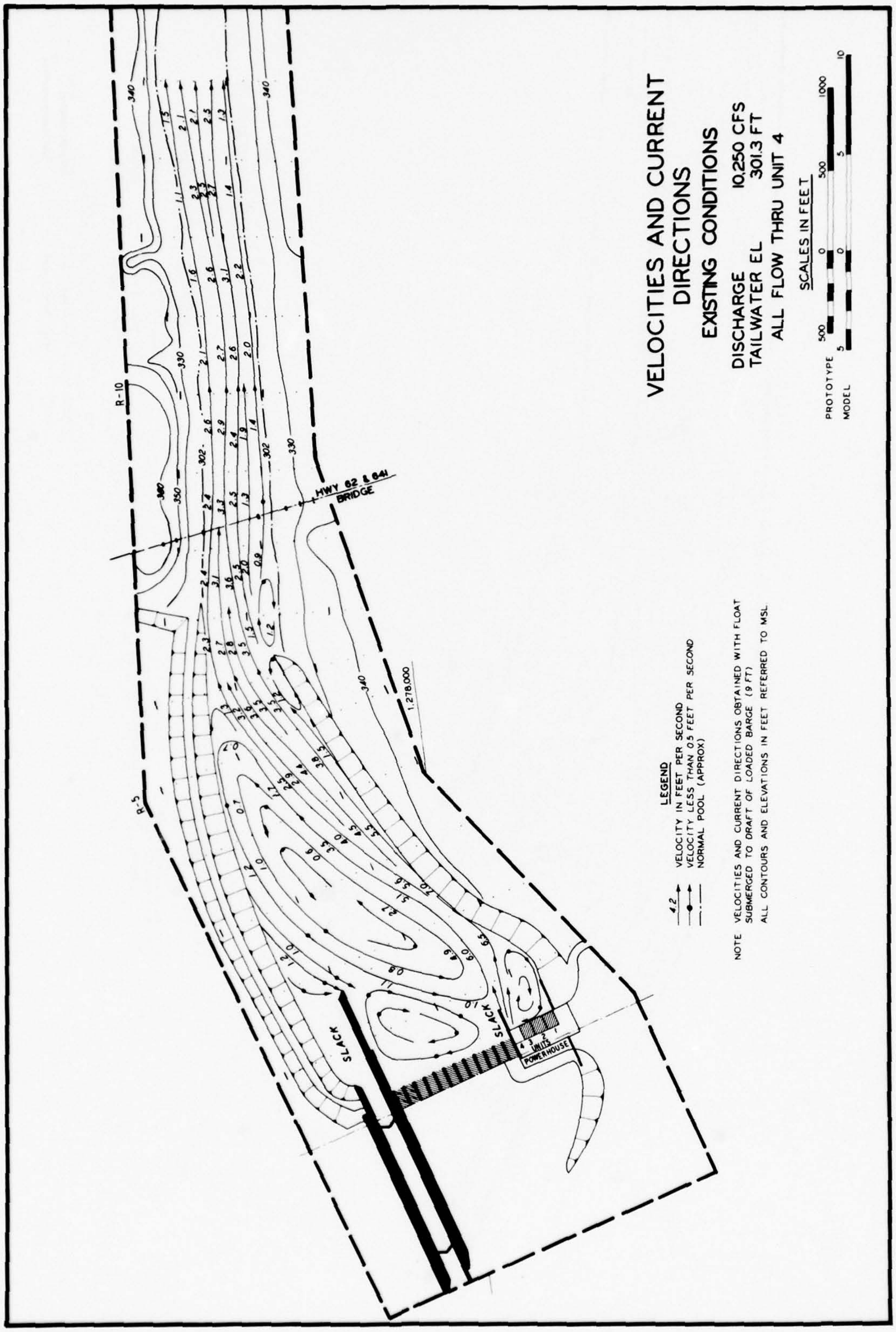
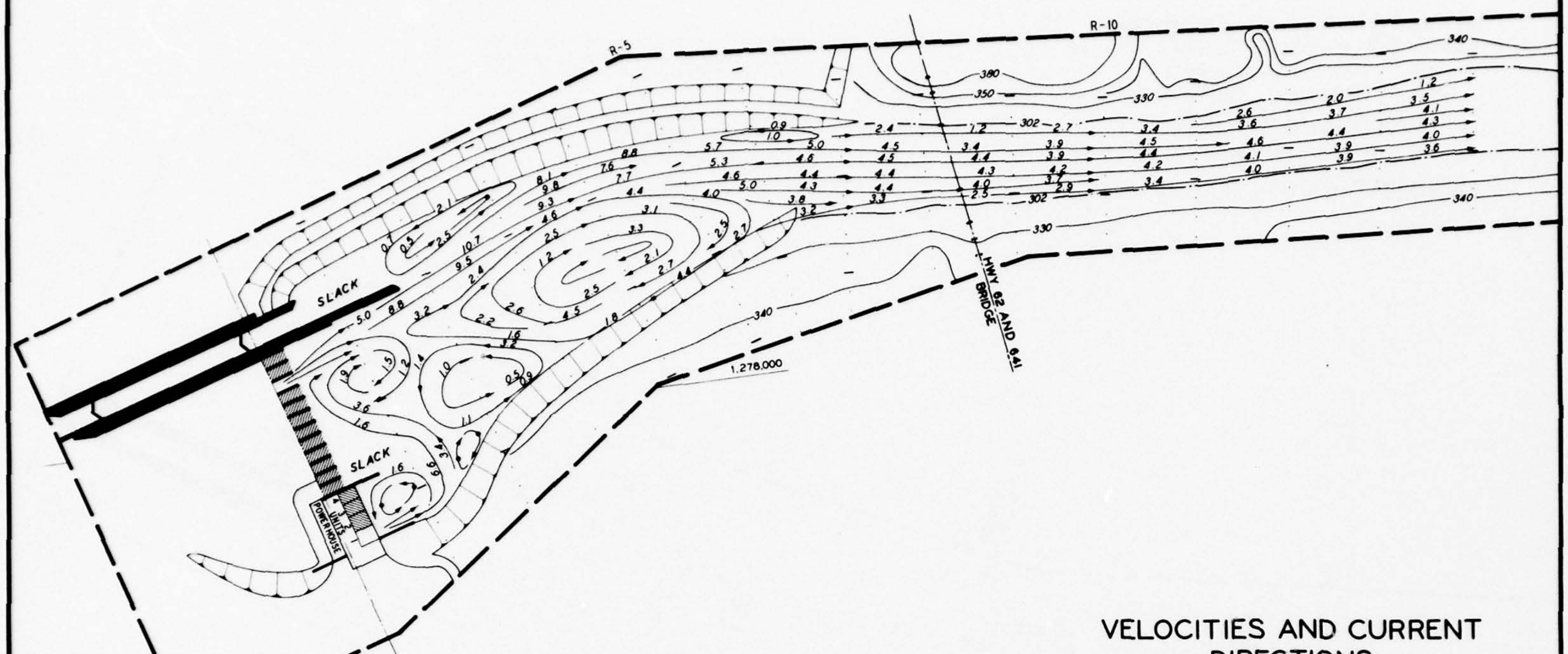

VELOCITIES AND CURRENT DIRECTIONS
EXISTING CONDITIONS
DISCHARGE 10,250 CFS
TAILWATER EL 301.3 FT
ALL FLOW THRU UNIT 1
SCALES IN FEET
PROTOTYPE 500 0 500 1000
MODEL 5 0 5 10
LEGEND
VELOCITY IN FEET PER SECOND
VELOCITY LESS THAN 0.5 FEET PER SECOND
NORMAL POOL (APPROX)
NOTE VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9 FT)
ALL CONTOURS AND ELEVATIONS IN FEET REFERRED TO MSL
HWY 62 & 641 BRIDGE
R-10
R-5
1,278,000
UNITS
POWERHOUSE

PLATE 7



VELOCITIES AND CURRENT DIRECTIONS
EXISTING CONDITIONS
DISCHARGE 10,250 CFS
TAILWATER EL 301.3 FT
ALL FLOW THRU UNIT 4
SCALES IN FEET
PROTOTYPE
MODEL
LEGEND
VELOCITY IN FEET PER SECOND
VELOCITY LESS THAN 0.5 FEET PER SECOND
NORMAL POOL (APPROX)
NOTE VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9 FT)
ALL CONTOURS AND ELEVATIONS IN FEET REFERRED TO MSL
HWY 82 & 641 BRIDGE
R-10
R-5
SLACK
SLACK
UNITS
POWERHOUSE
1,278,000

PLATE 8



VELOCITIES AND CURRENT DIRECTIONS
EXISTING CONDITIONS

DISCHARGE 20,500 CFS
TAILWATER EL 302.6 FT
DISCHARGE THRU UNIT 1 10.250 CFS
DISCHARGE THRU GATE 3 10,250 CFS

SCALES IN FEET

PROTOTYPE 500 0 500 1000
MODEL 5 0 5 10

LEGEND

4.2 VELOCITY IN FEET PER SECOND
VELOCITY LESS THAN 0.5 FEET PER SECOND
NORMAL POOL (APPROX)

NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9 FT)
ALL CONTOURS AND ELEVATIONS IN FEET REFERRED TO MSL

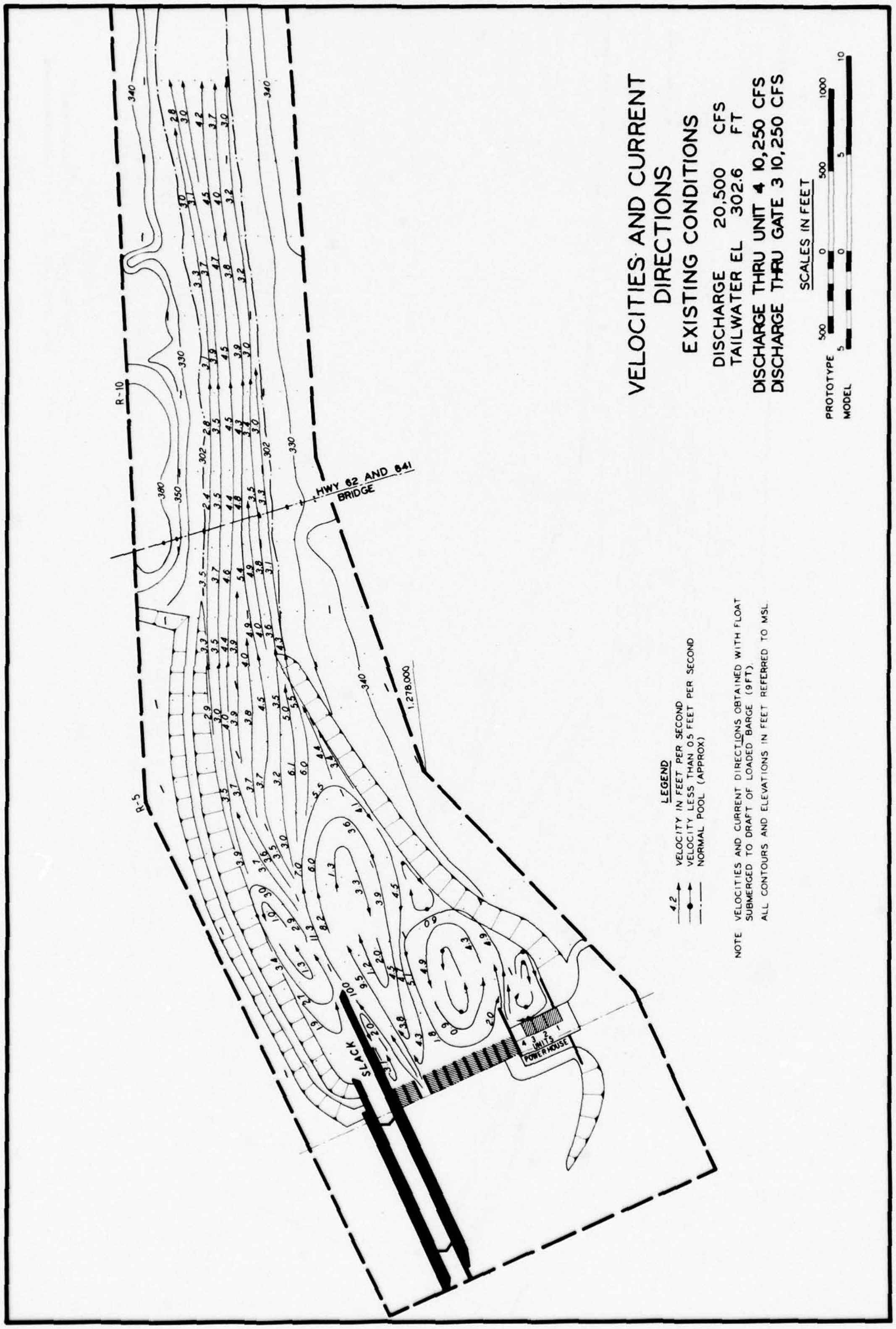
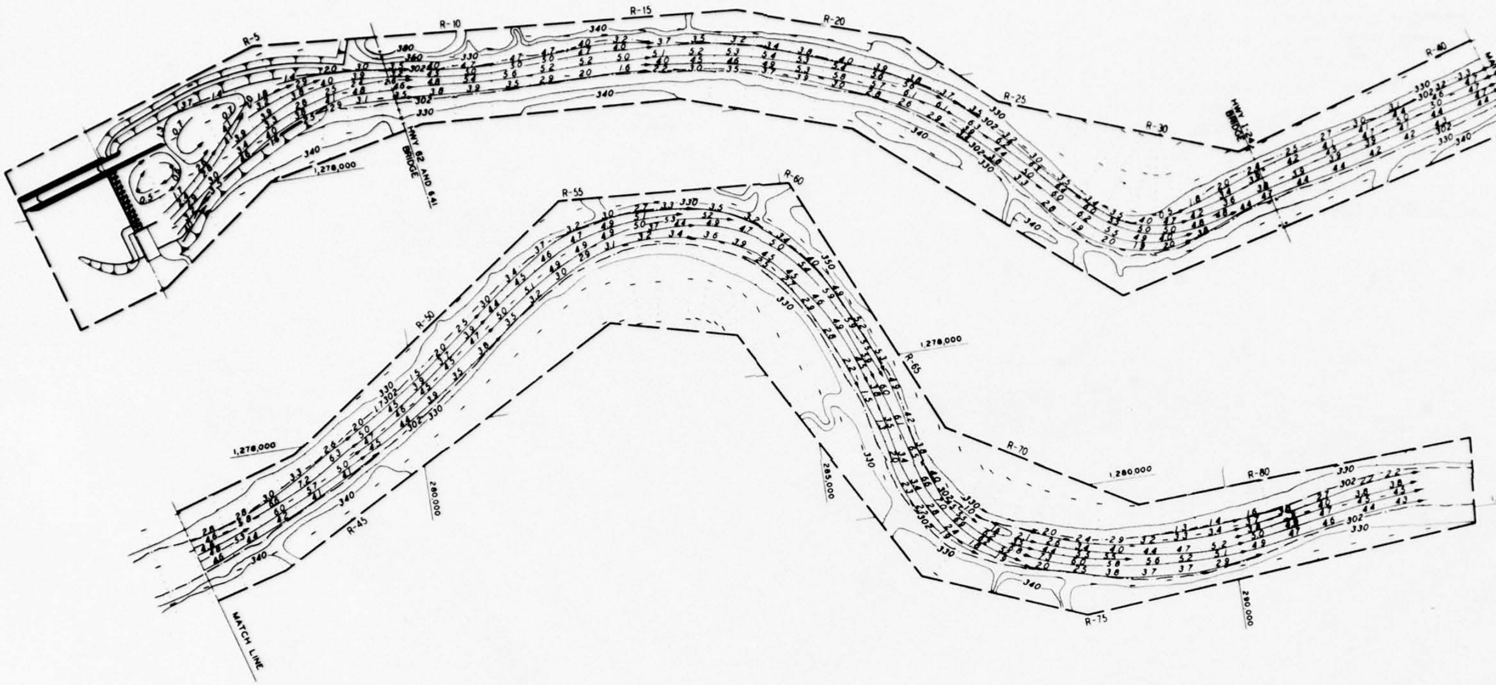

VELOCITIES AND CURRENT DIRECTIONS
EXISTING CONDITIONS
DISCHARGE 20,500 CFS
TAILWATER EL 302.6 FT
DISCHARGE THRU UNIT 4 10,250 CFS
DISCHARGE THRU GATE 3 10,250 CFS
SCALES IN FEET
PROTOTYPE
MODEL
LEGEND
VELOCITY IN FEET PER SECOND
VELOCITY LESS THAN 0.5 FEET PER SECOND
NORMAL POOL (APPROX)
NOTE VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9FT).
ALL CONTOURS AND ELEVATIONS IN FEET REFERRED TO MSL.
HWY 62 AND 641 BRIDGE
POWER HOUSE
UNITS
SLACK
R-10
R-5
1,278,000

PLATE 10



LEGEND

42 → VELOCITY IN FEET PER SECOND
→•→ VELOCITY LESS THAN 0.5 FEET PER SECOND
—·— NORMAL POOL (APPROX)

NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9 FT).
ALL CONTOURS AND ELEVATIONS IN FEET REFERRED TO MSL.

VELOCITIES AND CURRENT DIRECTIONS
EXISTING CONDITIONS

DISCHARGE 40,320 CFS
TAILWATER EL 310.7 FT
DISCHARGE THRU UNITS 1, 2, 3, AND 4

SCALES IN FEET

PROTOTYPE 500 0 500 1000 1500
MODEL 5 0 5 10 15

PLATE 11

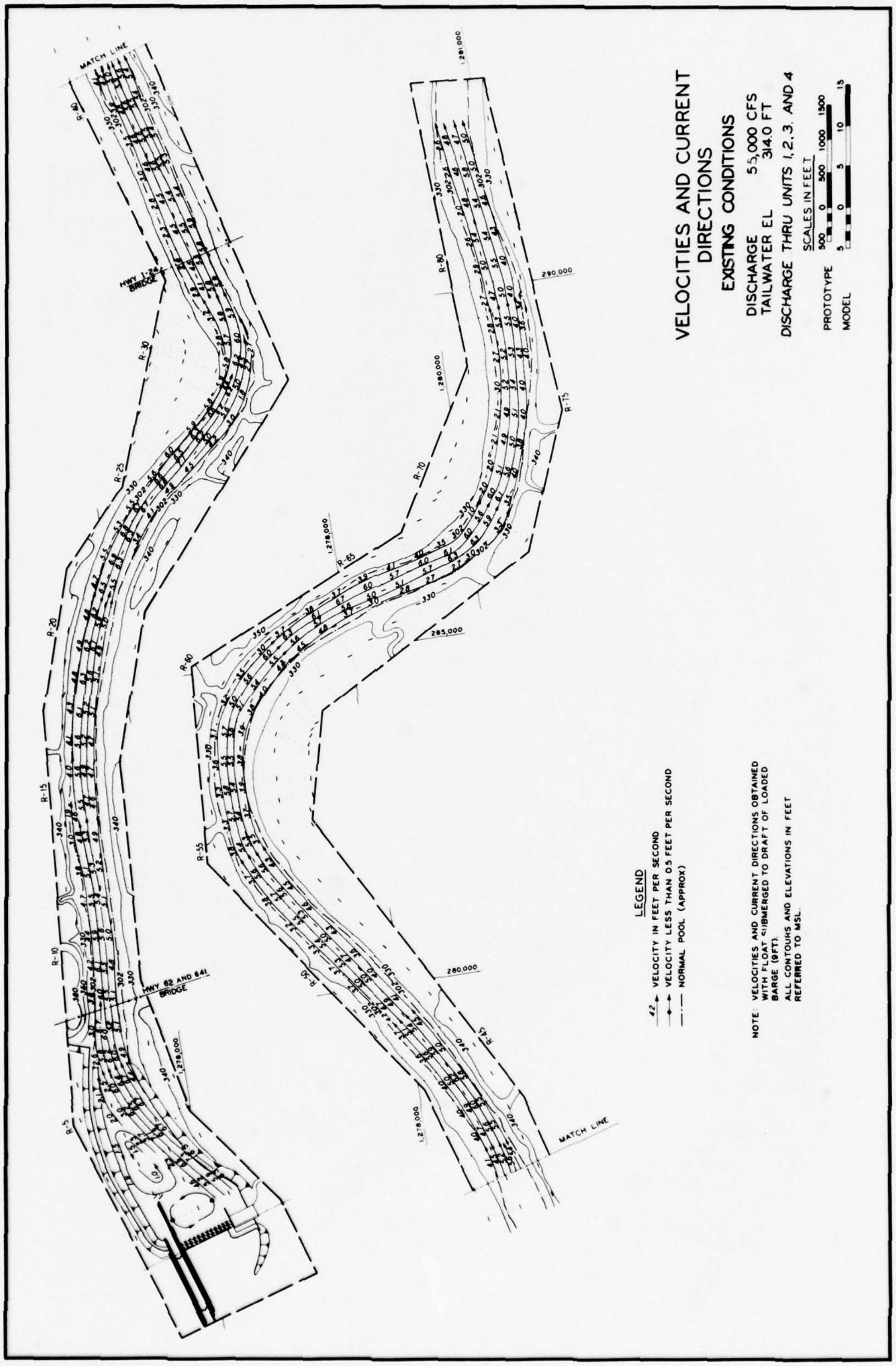
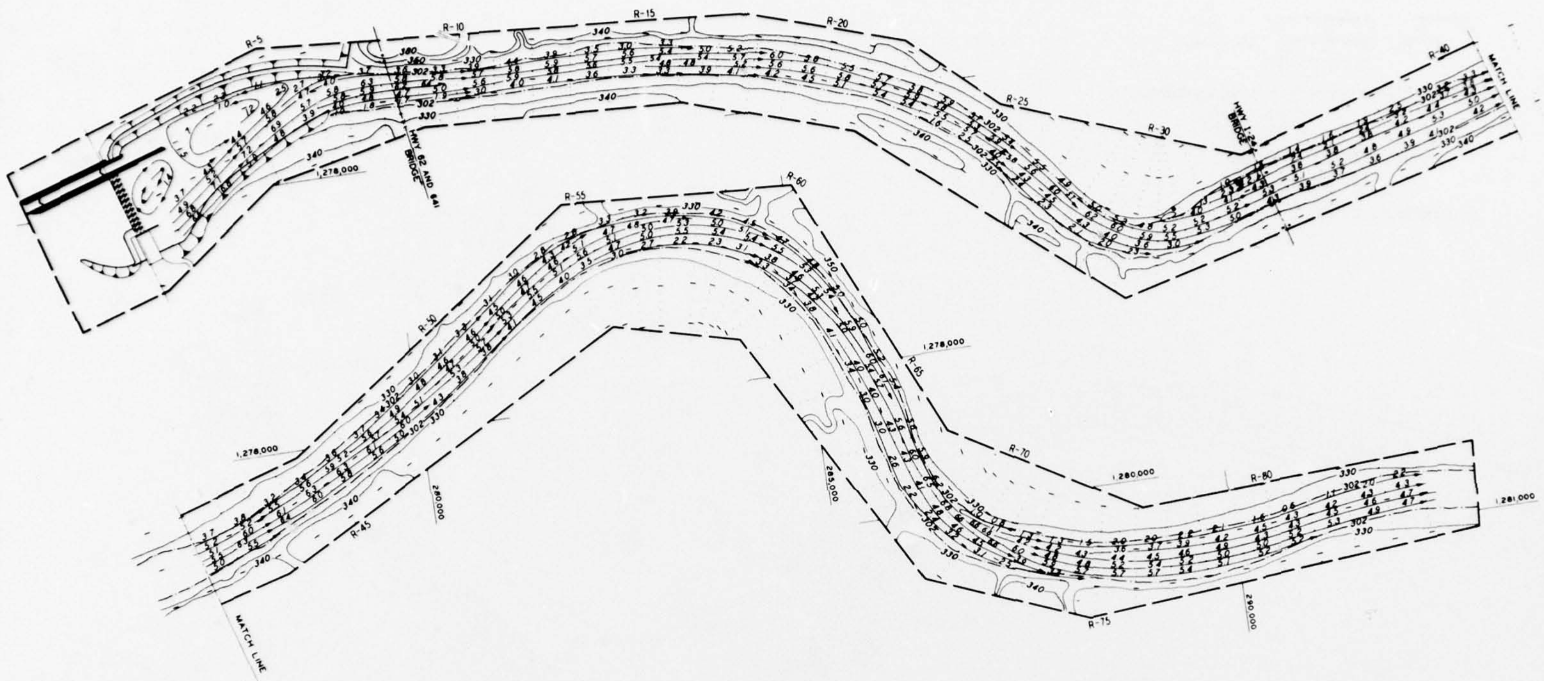

VELOCITIES AND CURRENT DIRECTIONS
EXISTING CONDITIONS
DISCHARGE 55,000 CFS
TAILWATER EL 314.0 FT
DISCHARGE THRU UNITS 1, 2, 3, AND 4
SCALES IN FEET
PROTOTYPE 500 0 500 1000 1500
MODEL 5 0 5 10 15
LEGEND
42 VELOCITY IN FEET PER SECOND
VELOCITY LESS THAN 0.5 FEET PER SECOND
NORMAL POOL (APPROX)
NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9FT).
ALL CONTOURS AND ELEVATIONS IN FEET REFERRED TO MSL.
MATCH LINE
HWY I-24 BRIDGE
HWY 62 AND 641 BRIDGE

PLATE 12



LEGEND

- 42 → VELOCITY IN FEET PER SECOND
- •→ VELOCITY LESS THAN 0.5 FEET PER SECOND
- —·— NORMAL POOL (APPROX)

NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9 FT).
ALL CONTOURS AND ELEVATIONS IN FEET REFERRED TO MSL.

VELOCITIES AND CURRENT DIRECTIONS

EXISTING CONDITIONS

DISCHARGE 55,000 CFS
TAILWATER EL 317.1 FT
DISCHARGE THRU UNITS 1, 2, 3, AND 4

SCALES IN FEET

PROTOTYPE 500 0 500 1000 1500
MODEL 5 0 5 10 15

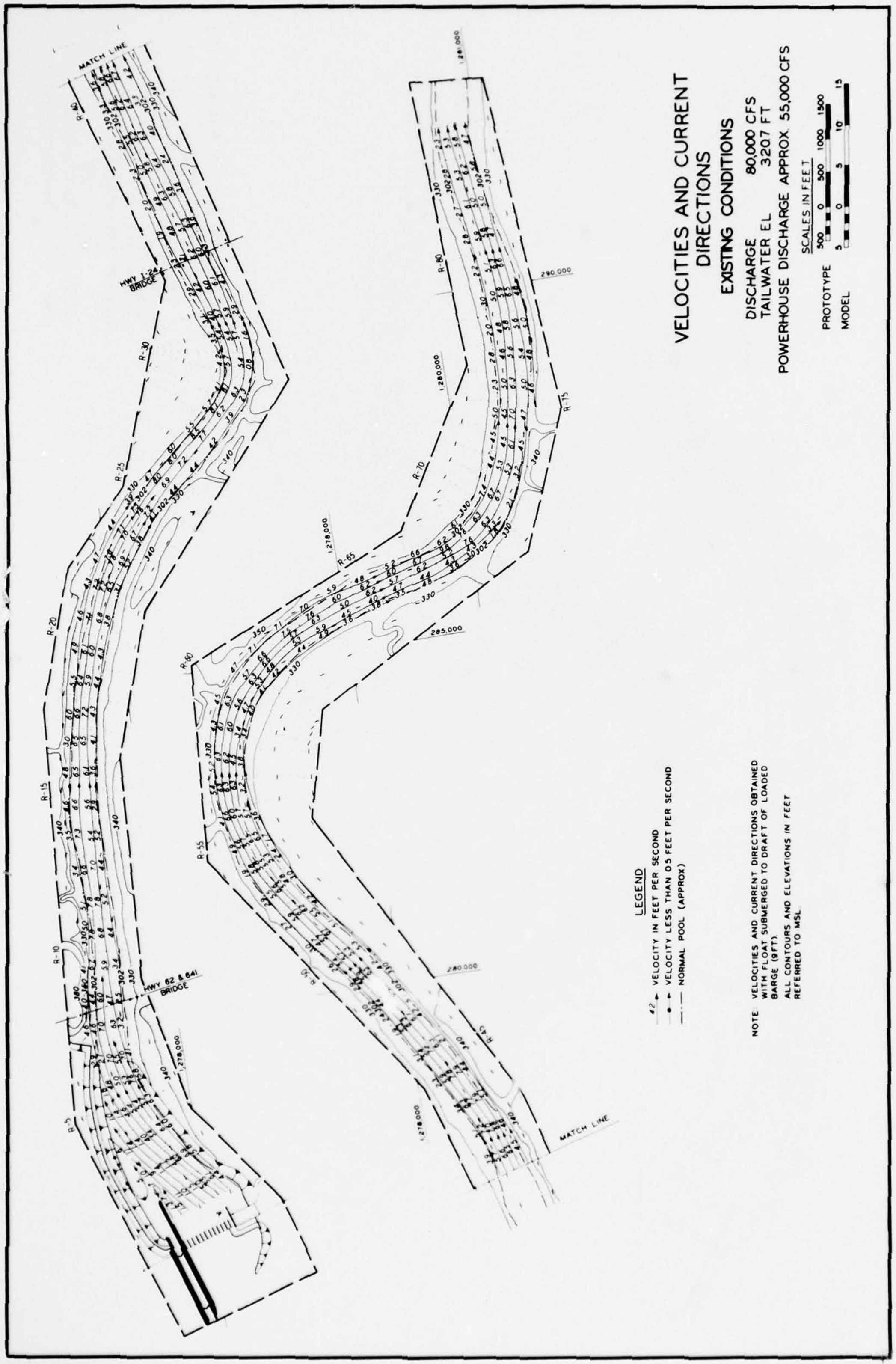
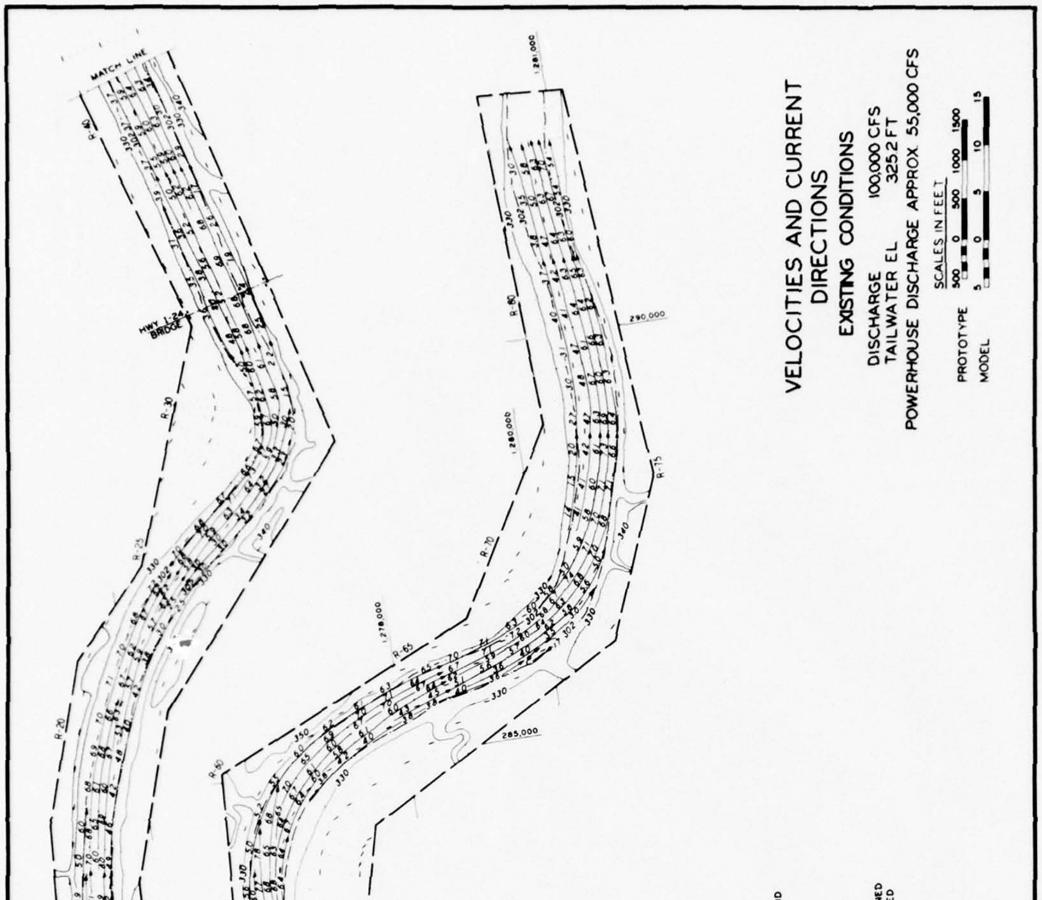

VELOCITIES AND CURRENT DIRECTIONS
EXISTING CONDITIONS
DISCHARGE 80,000 CFS
TAILWATER EL 320.7 FT
POWERHOUSE DISCHARGE APPROX 55,000 CFS
SCALES IN FEET
PROTOTYPE 500 0 500 1000 1500
MODEL 5 0 5 10 15
LEGEND
VELOCITY IN FEET PER SECOND
VELOCITY LESS THAN 0.5 FEET PER SECOND
NORMAL POOL (APPROX)
NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9 FT).
ALL CONTOURS AND ELEVATIONS IN FEET REFERRED TO MSL.
MATCH LINE
MATCH LINE
HWY 62 & 641 BRIDGE
HWY I-24 BRIDGE

PLATE 14



VELOCITIES AND CURRENT DIRECTIONS
EXISTING CONDITIONS
DISCHARGE 100,000 CFS
TAILWATER EL 325.2 FT
POWERHOUSE DISCHARGE APPROX 55,000 CFS
SCALES IN FEET
PROTOTYPE 500 0 500 1000 1500
MODEL 5 0 5 10 15
LEGEND
4.2 VELOCITY IN FEET PER SECOND
VELOCITY LESS THAN 0.5 FEET PER SECOND
NORMAL POOL (APPROX)
NOTE VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9 FT)
ALL CONTOURS AND ELEVATIONS IN FEET REFERRED TO MSL.
MATCH LINE
HWY I-24 BRIDGE
HWY 62 & 641 BRIDGE
MATCH LINE

PLATE 15

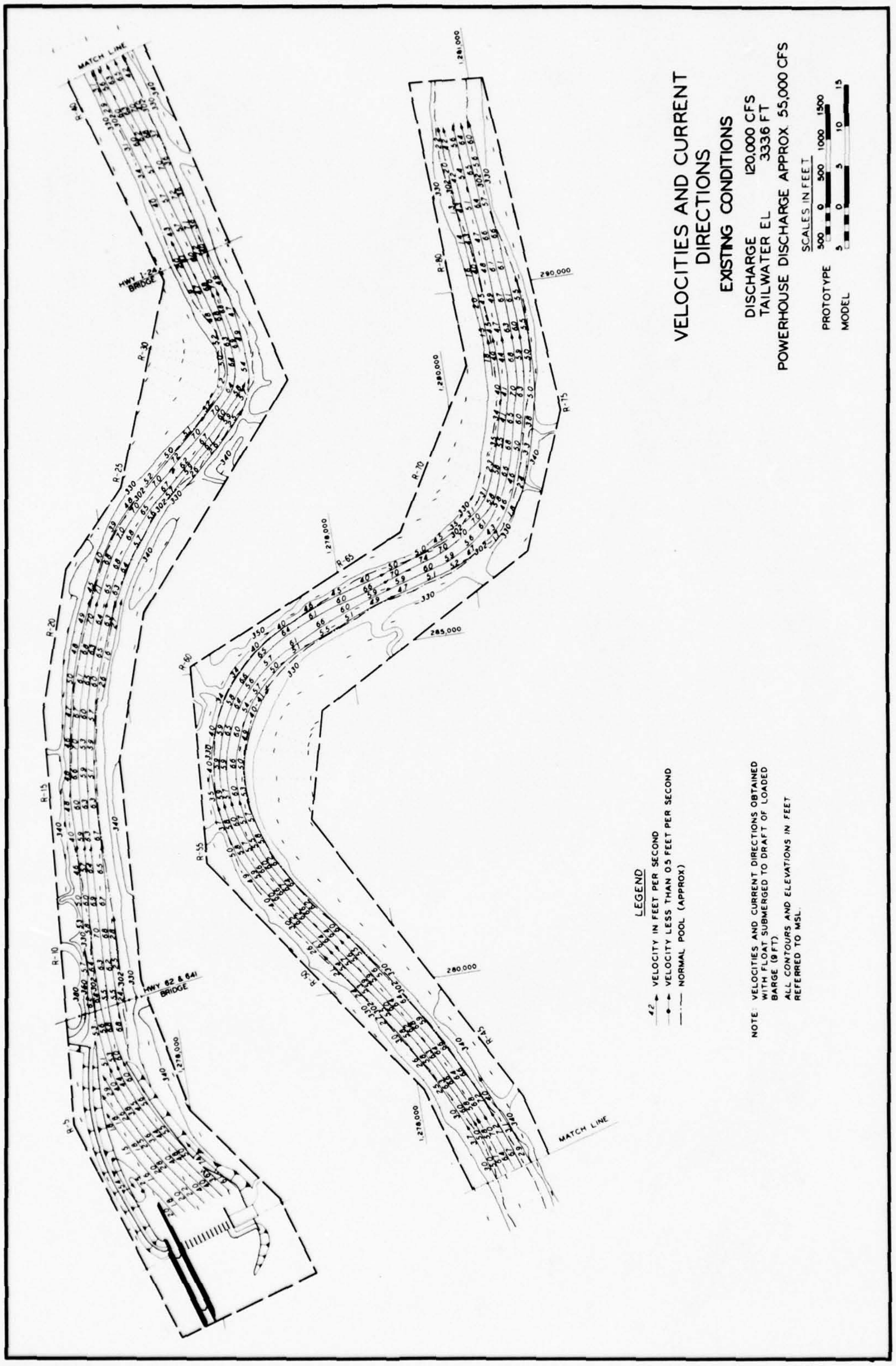
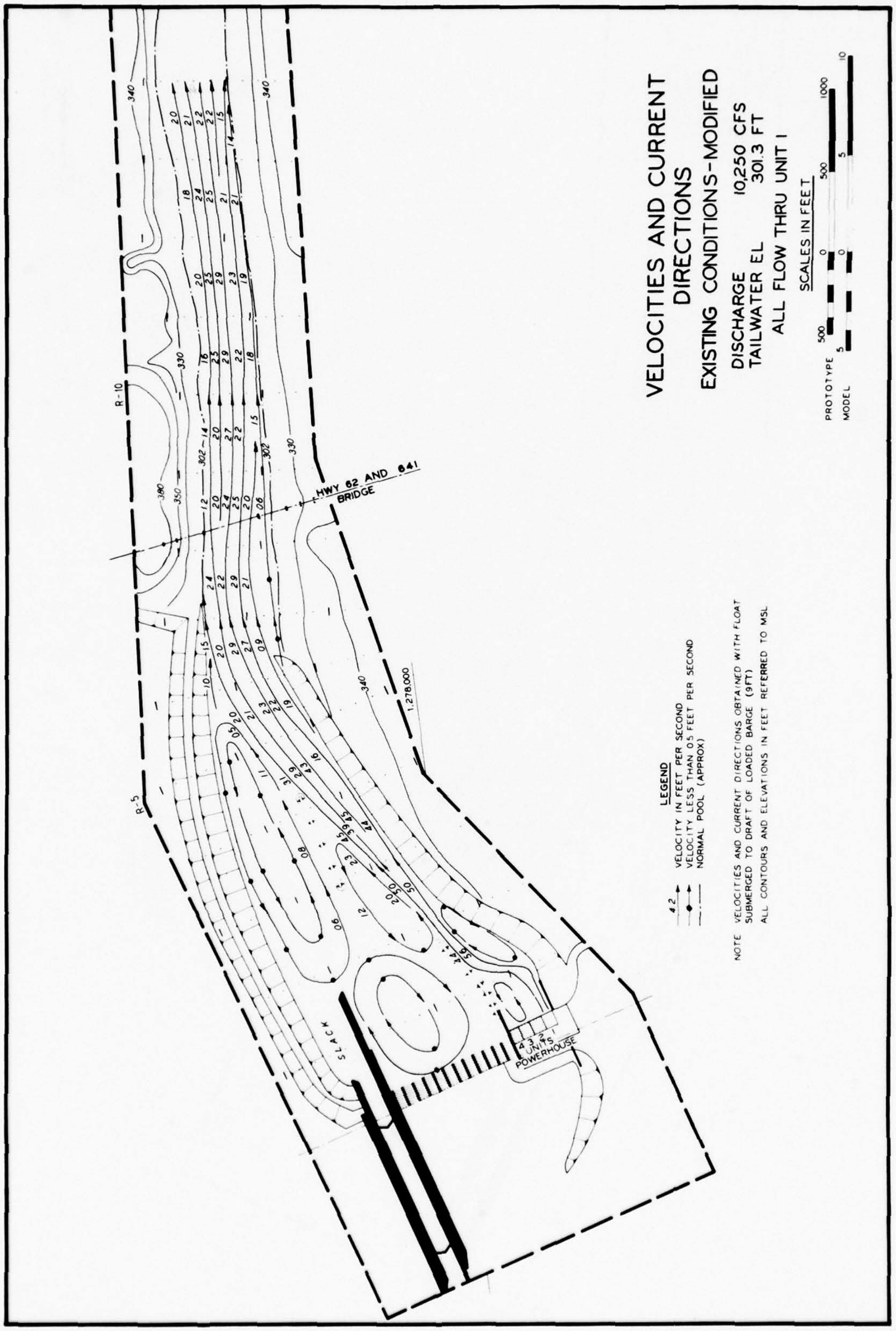

VELOCITIES AND CURRENT DIRECTIONS
EXISTING CONDITIONS
DISCHARGE 120,000 CFS
TAILWATER EL. 3336 FT
POWERHOUSE DISCHARGE APPROX. 55,000 CFS
SCALES IN FEET
PROTOTYPE 500 0 500 1000 1500
MODEL 5 0 5 10 15
LEGEND
42 VELOCITY IN FEET PER SECOND
VELOCITY LESS THAN 0.5 FEET PER SECOND
NORMAL POOL (APPROX)
NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9 FT).
ALL CONTOURS AND ELEVATIONS IN FEET REFERRED TO MSL.
MATCH LINE
HWY 62 & 641 BRIDGE
HWY I-24 BRIDGE
MATCH LINE

PLATE 16


VELOCITIES AND CURRENT DIRECTIONS
EXISTING CONDITIONS-MODIFIED
DISCHARGE 10,250 CFS
TAILWATER EL 301.3 FT
ALL FLOW THRU UNIT 1
SCALES IN FEET
PROTOTYPE
MODEL
LEGEND
VELOCITY IN FEET PER SECOND
VELOCITY LESS THAN 0.5 FEET PER SECOND
NORMAL POOL (APPROX)
NOTE VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9FT)
ALL CONTOURS AND ELEVATIONS IN FEET REFERRED TO MSL
HWY 62 AND 641 BRIDGE
R-10
R-5
SLACK
UNITS
POWERHOUSE
1,278,000

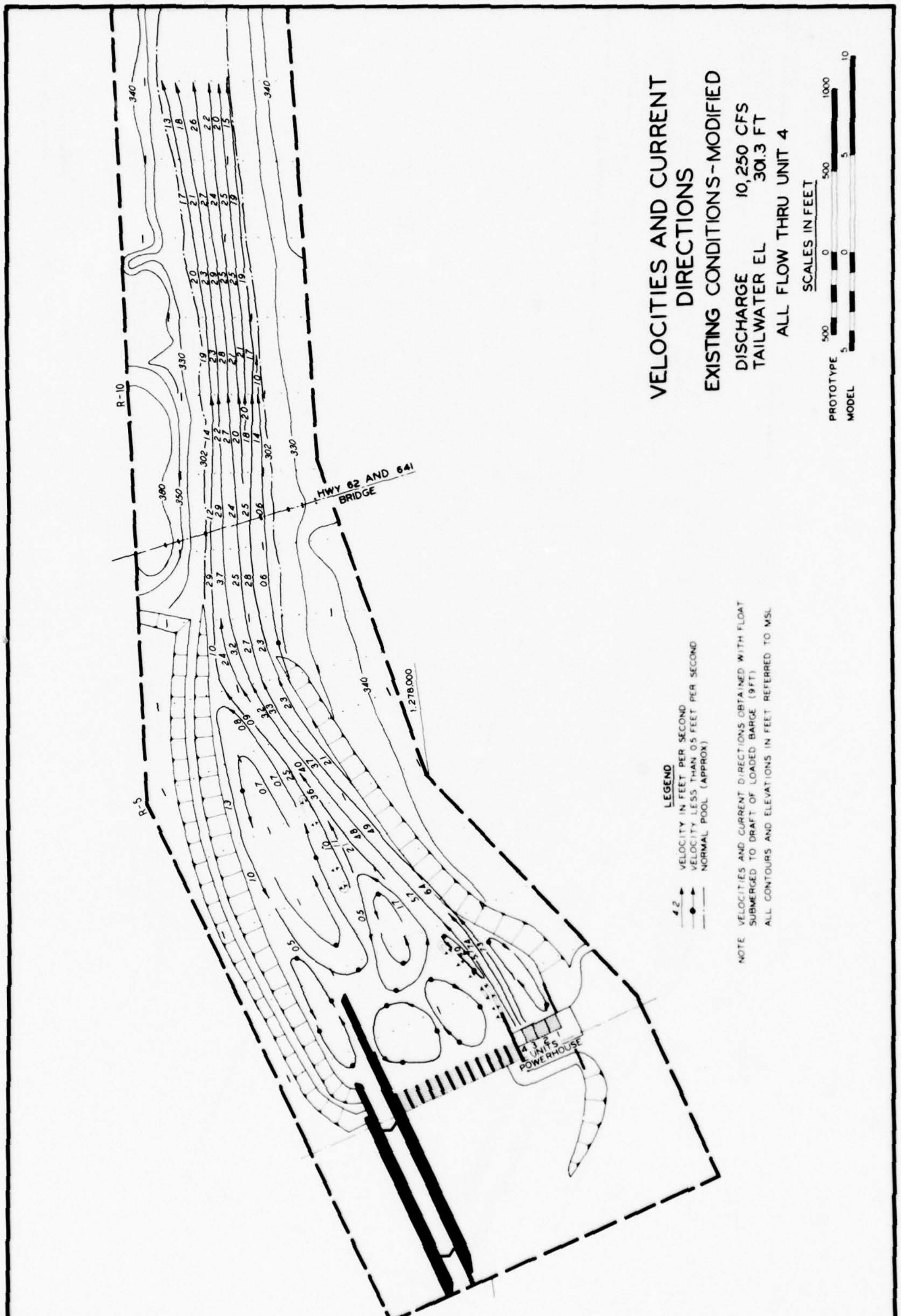
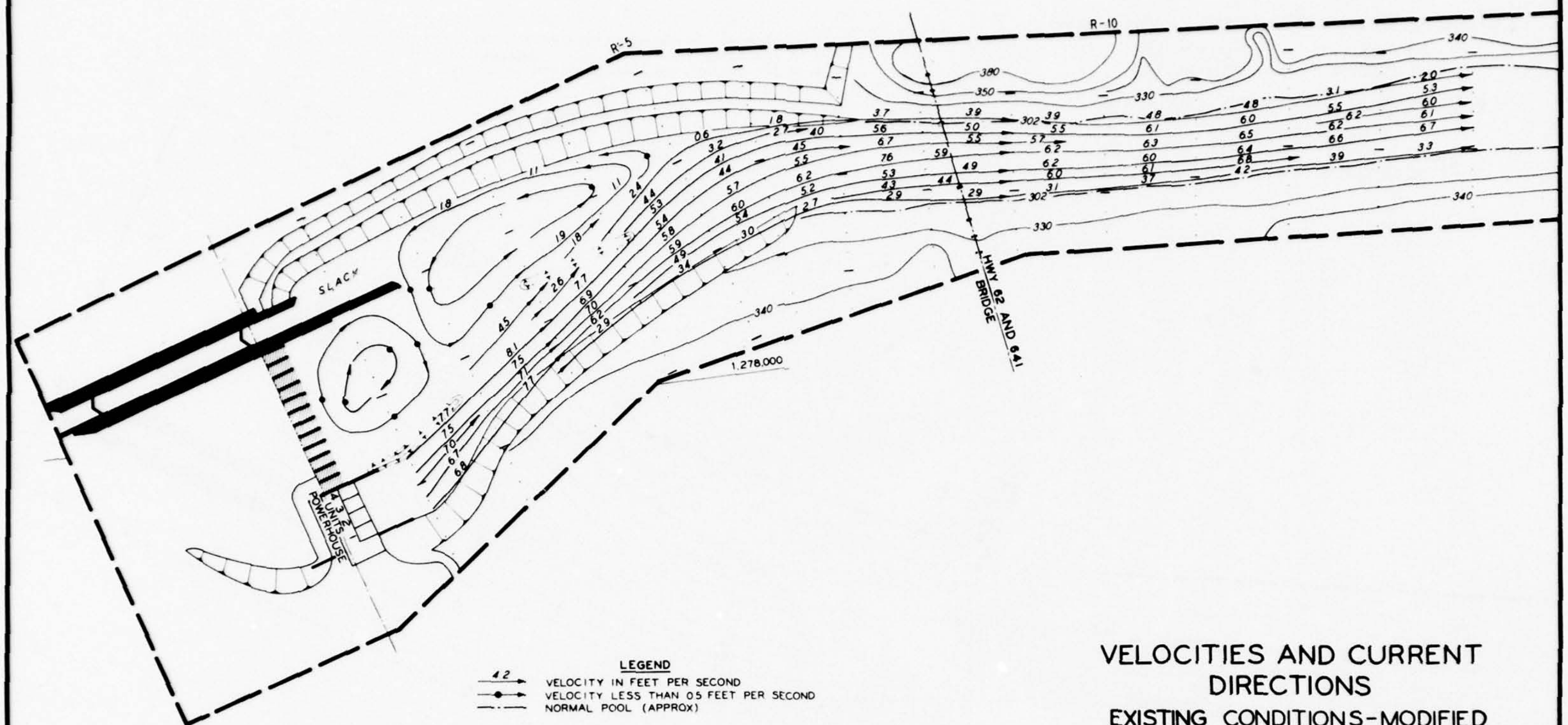

VELOCITIES AND CURRENT DIRECTIONS
EXISTING CONDITIONS-MODIFIED
DISCHARGE 10,250 CFS
TAILWATER EL 301.3 FT
ALL FLOW THRU UNIT 4
SCALES IN FEET
PROTOTYPE
MODEL
LEGEND
VELOCITY IN FEET PER SECOND
VELOCITY LESS THAN 0.5 FEET PER SECOND
NORMAL POOL (APPROX)
NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9 FT)
ALL CONTOURS AND ELEVATIONS IN FEET REFERRED TO MSL
HWY 62 AND 641 BRIDGE
POWERHOUSE
UNITS
R-10
R-5
1,278,000

PLATE 18



LEGEND

42 → VELOCITY IN FEET PER SECOND
→•→ VELOCITY LESS THAN 0.5 FEET PER SECOND
—·— NORMAL POOL (APPROX)

NOTE VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9 FT)
ALL CONTOURS AND ELEVATIONS IN FEET REFERRED TO MSL

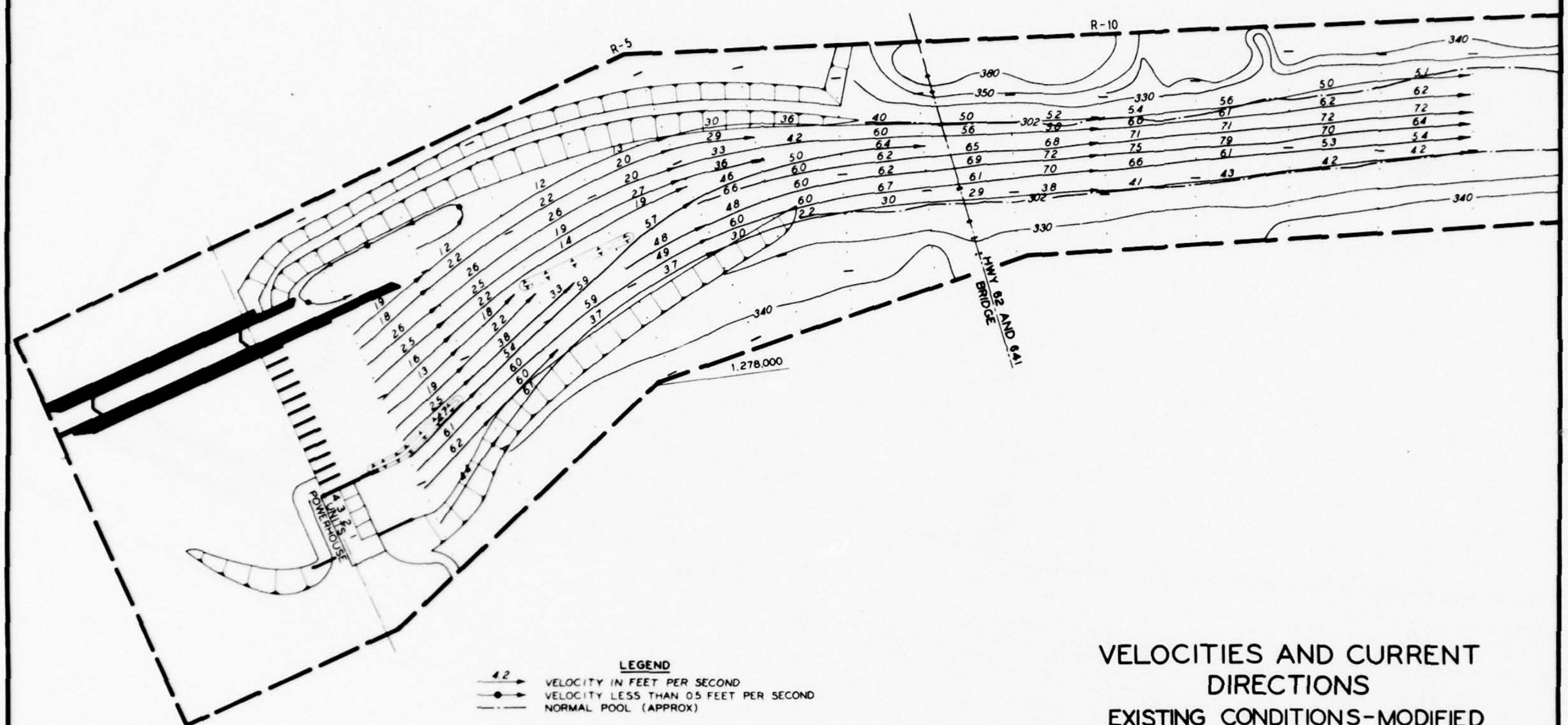
VELOCITIES AND CURRENT DIRECTIONS

EXISTING CONDITIONS-MODIFIED

DISCHARGE 55,000 CFS
TAILWATER EL 314.1 FT
ALL FLOW THRU POWERHOUSE

SCALES IN FEET

PROTOTYPE 500 0 500 1000
MODEL 5 0 5 10



LEGEND

- 4.2 → VELOCITY IN FEET PER SECOND
- •→ VELOCITY LESS THAN 0.5 FEET PER SECOND
- —·— NORMAL POOL (APPROX)

NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9 FT)
ALL CONTOURS AND ELEVATIONS IN FEET REFERRED TO MSL

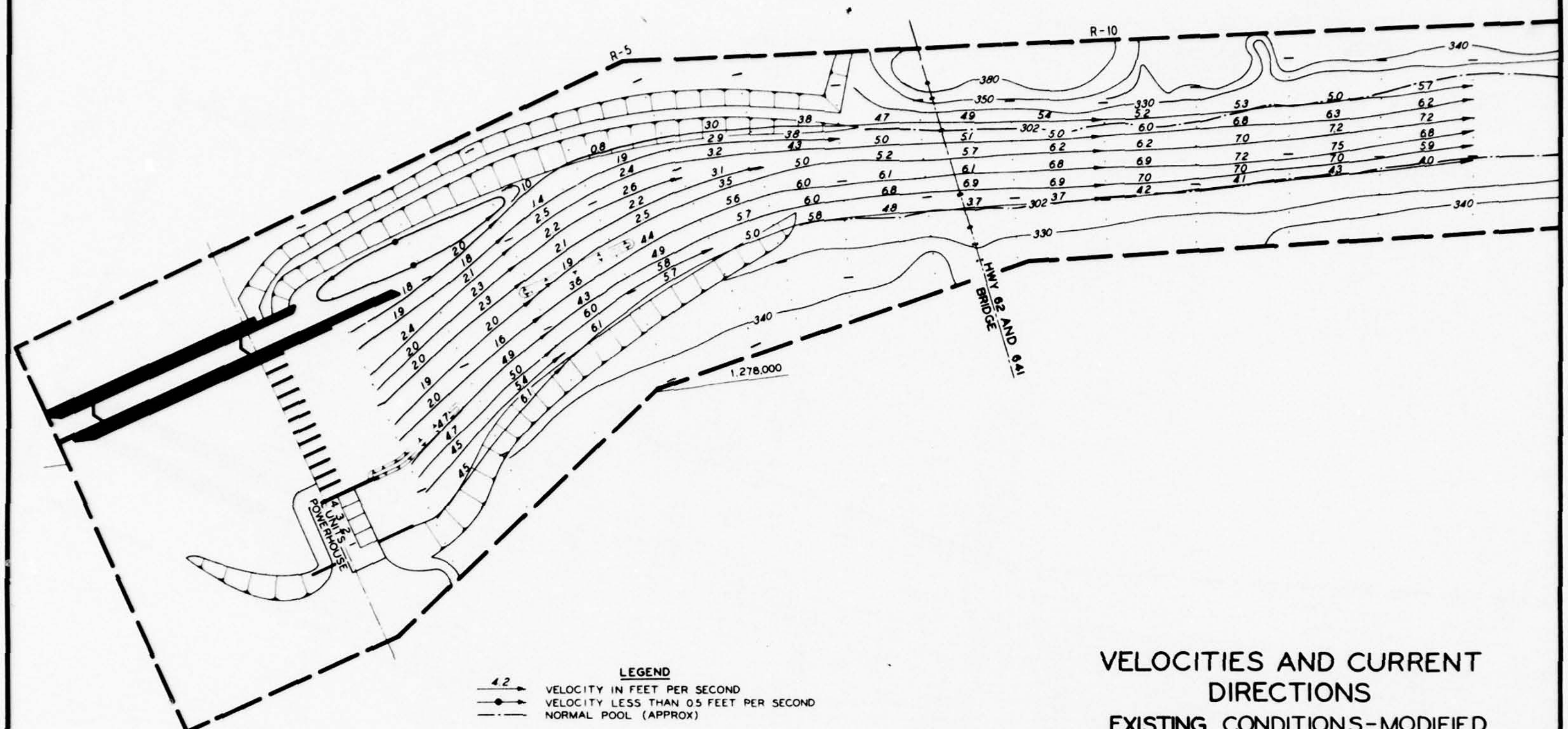
VELOCITIES AND CURRENT DIRECTIONS

EXISTING CONDITIONS-MODIFIED

DISCHARGE 80,000 CFS
TAILWATER EL 320.7 FT
POWERHOUSE DISCHARGE APPROX. 55,000 CFS

SCALES IN FEET

PROTOTYPE 500 0 500 1000
MODEL 5 0 5 10



LEGEND

- 4.2 → VELOCITY IN FEET PER SECOND
- —•→ VELOCITY LESS THAN 0.5 FEET PER SECOND
- —·— NORMAL POOL (APPROX)

NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9 FT)

ALL CONTOURS AND ELEVATIONS IN FEET REFERRED TO MSL

VELOCITIES AND CURRENT DIRECTIONS

EXISTING CONDITIONS-MODIFIED

DISCHARGE 100,000 CFS

TAILWATER EL 325.2 FT

POWERHOUSE DISCHARGE APPROX. 55,000 CFS

SCALES IN FEET

PROTOTYPE 500 0 500 1000

MODEL 5 0 5 10

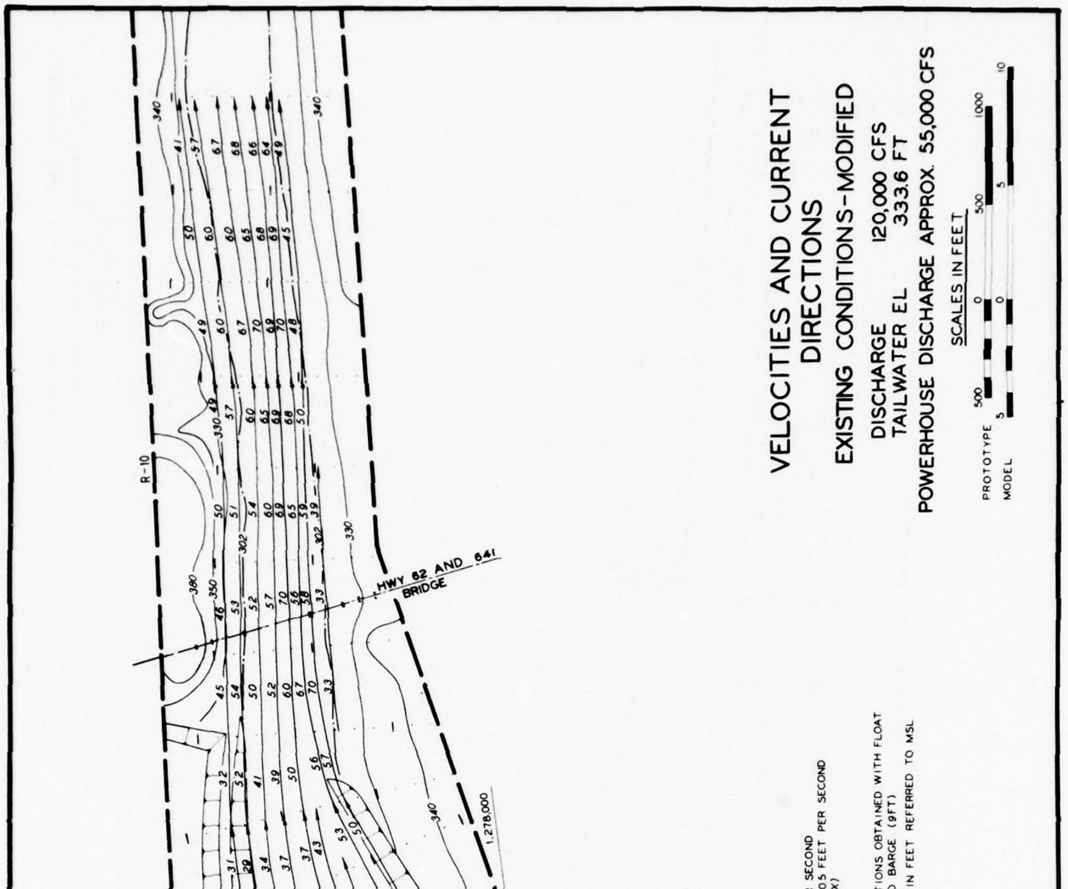
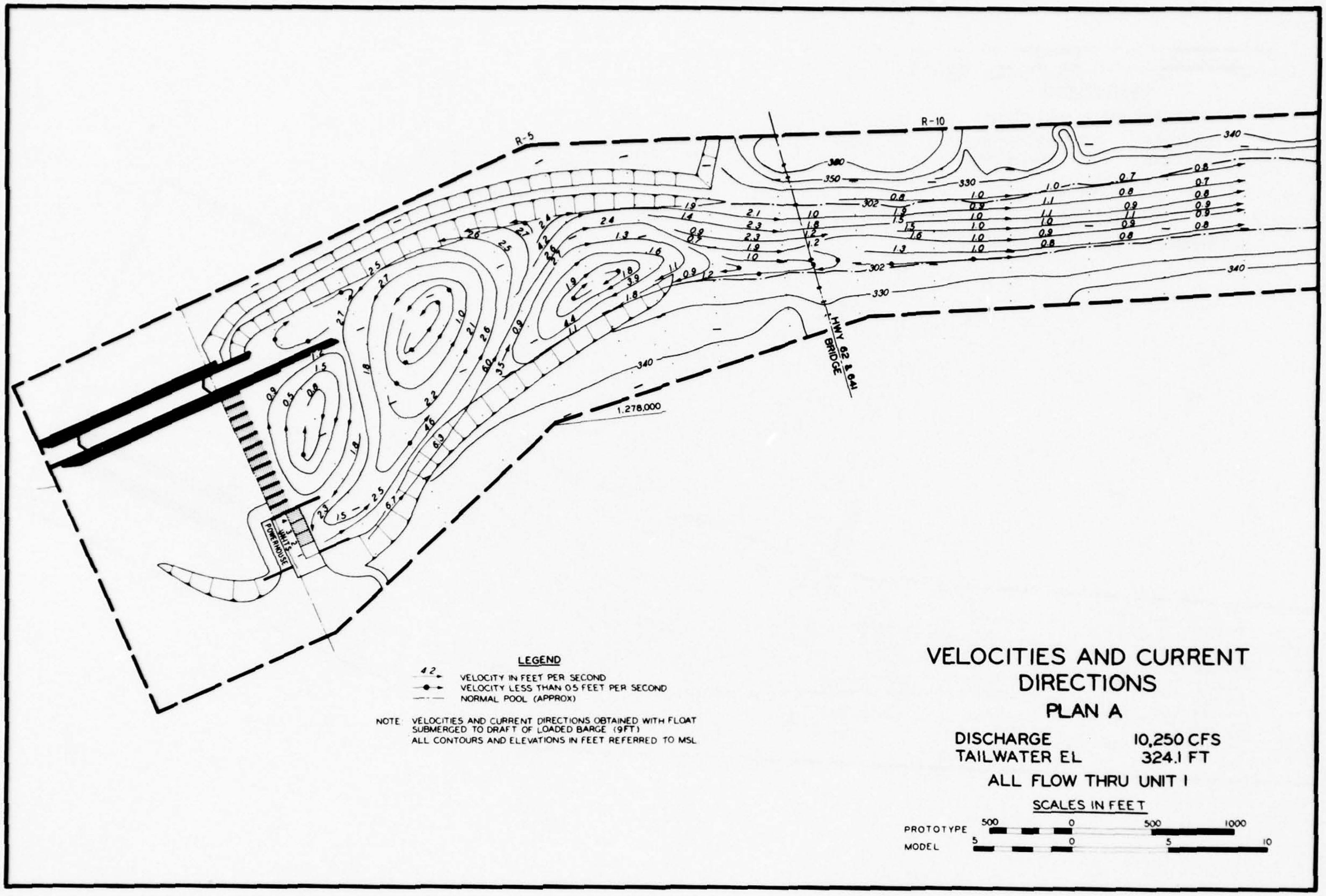

VELOCITIES AND CURRENT DIRECTIONS
EXISTING CONDITIONS-MODIFIED
DISCHARGE 120,000 CFS
TAILWATER EL 333.6 FT
POWERHOUSE DISCHARGE APPROX. 55,000 CFS
SCALES IN FEET
PROTOTYPE 500 0 500 1000
MODEL 5 0 5 10
LEGEND
4.2 VELOCITY IN FEET PER SECOND
VELOCITY LESS THAN 0.5 FEET PER SECOND
NORMAL POOL (APPROX)
NOTE VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9FT)
ALL CONTOURS AND ELEVATIONS IN FEET REFERRED TO MSL
HWY 62 AND 641 BRIDGE
R-10
R-5
1,278,000
UNITS
POWERHOUSE

PLATE 22



VELOCITIES AND CURRENT DIRECTIONS
PLAN A

DISCHARGE 10,250 CFS
TAILWATER EL 324.1 FT
ALL FLOW THRU UNIT 1

SCALES IN FEET
PROTOTYPE 500 0 500 1000
MODEL 5 0 5 10

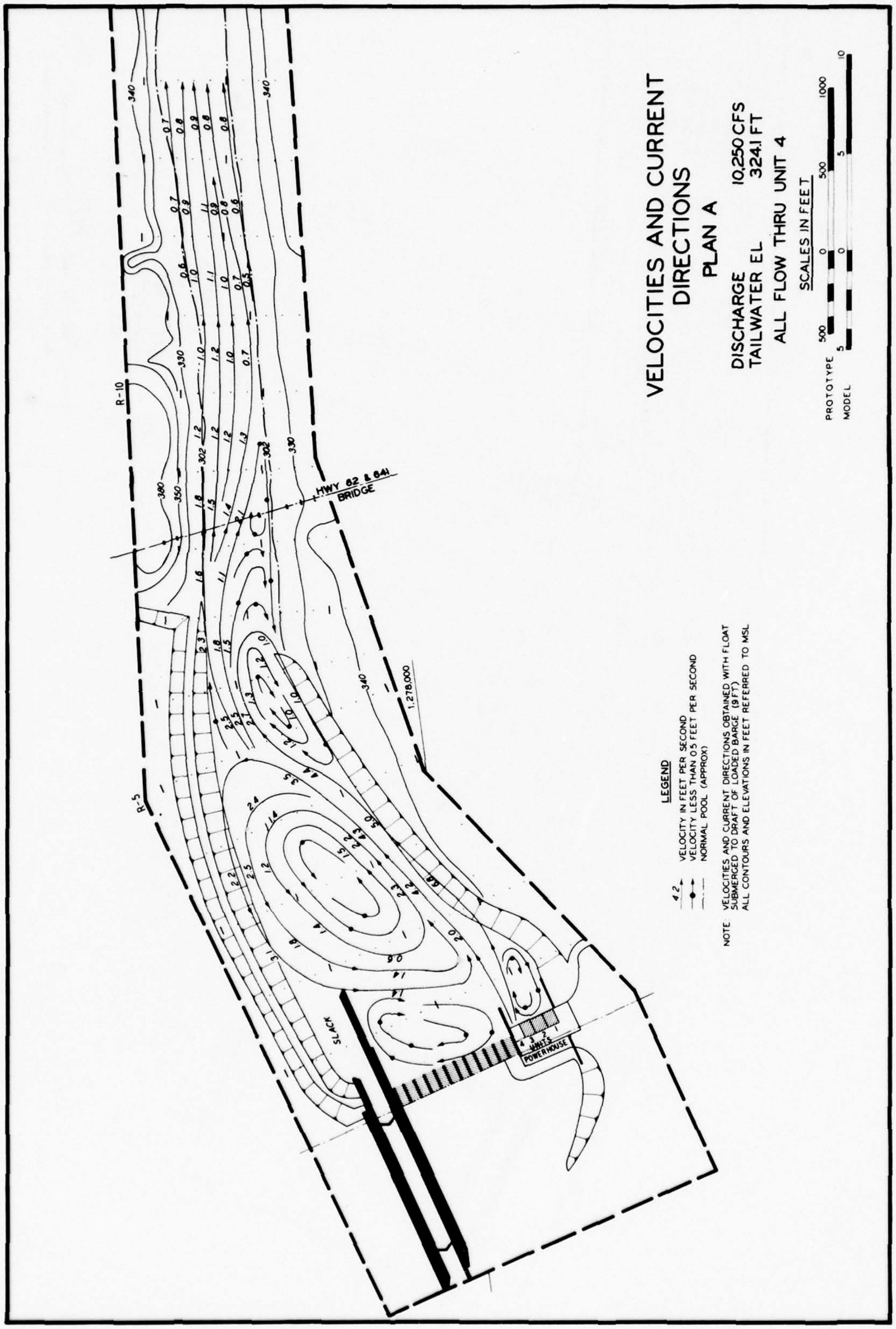
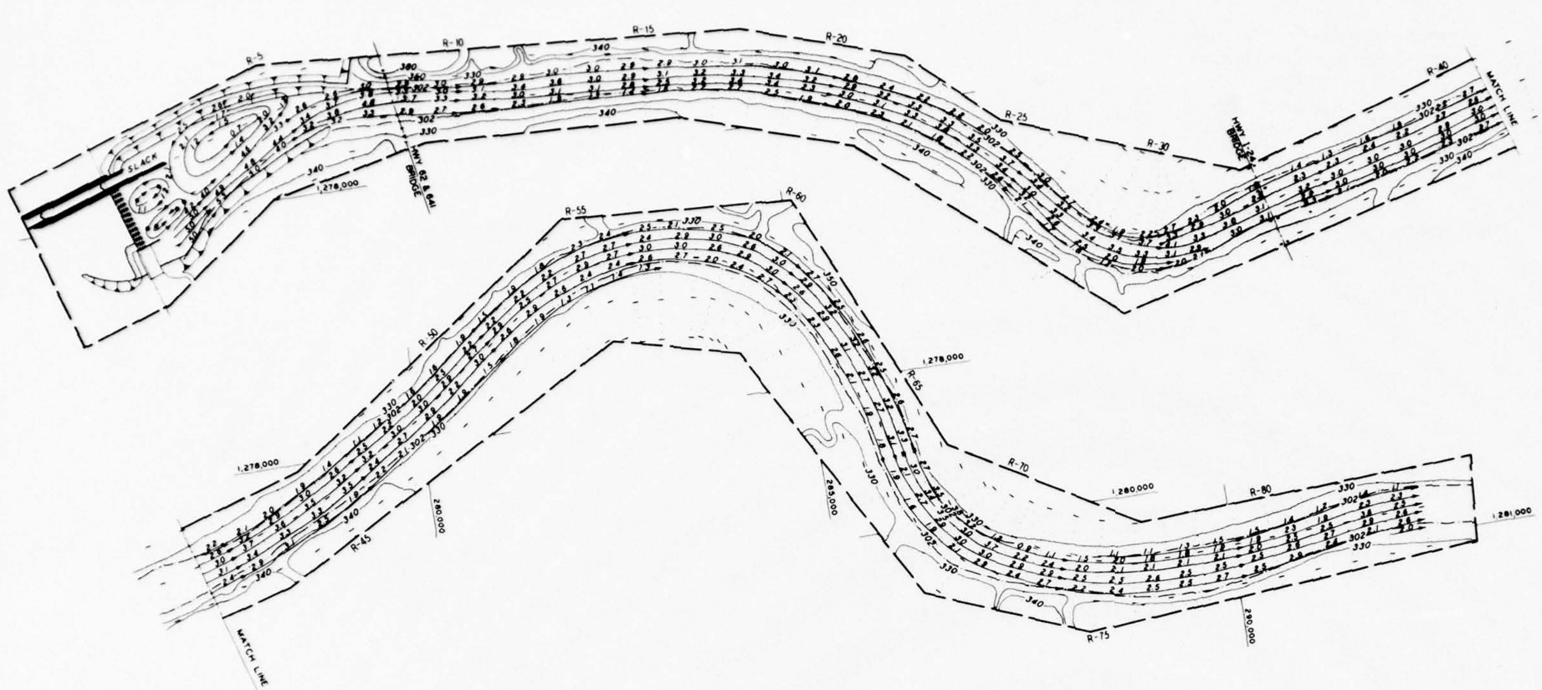

VELOCITIES AND CURRENT
DIRECTIONS
PLAN A
DISCHARGE 10,250 CFS
TAILWATER EL 324.1 FT
ALL FLOW THRU UNIT 4
SCALES IN FEET
PROTOTYPE 500 0 500 1000
MODEL 5 0 5 10
LEGEND
VELOCITY IN FEET PER SECOND
VELOCITY LESS THAN 0.5 FEET PER SECOND
NORMAL POOL (APPROX)
NOTE VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9 FT)
ALL CONTOURS AND ELEVATIONS IN FEET REFERRED TO MSL.
HWY 82 & 841
BRIDGE
R-10
R-5
1,278,000
SLACK
UNITS
POWERHOUSE

PLATE 24



LEGEND

42 → VELOCITY IN FEET PER SECOND

•→ VELOCITY LESS THAN 0.5 FEET PER SECOND

—·— NORMAL POOL (APPROX)

NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9 FT).

ALL CONTOURS AND ELEVATIONS IN FEET REFERRED TO MSL.

VELOCITIES AND CURRENT DIRECTIONS

PLAN A

DISCHARGE	40,320 CFS
TAILWATER EL	324.7 FT

ALL FLOW THRU POWERHOUSE

SCALES IN FEET

PROTOTYPE 500 0 500 1000 1500

MODEL 5 0 5 10 15

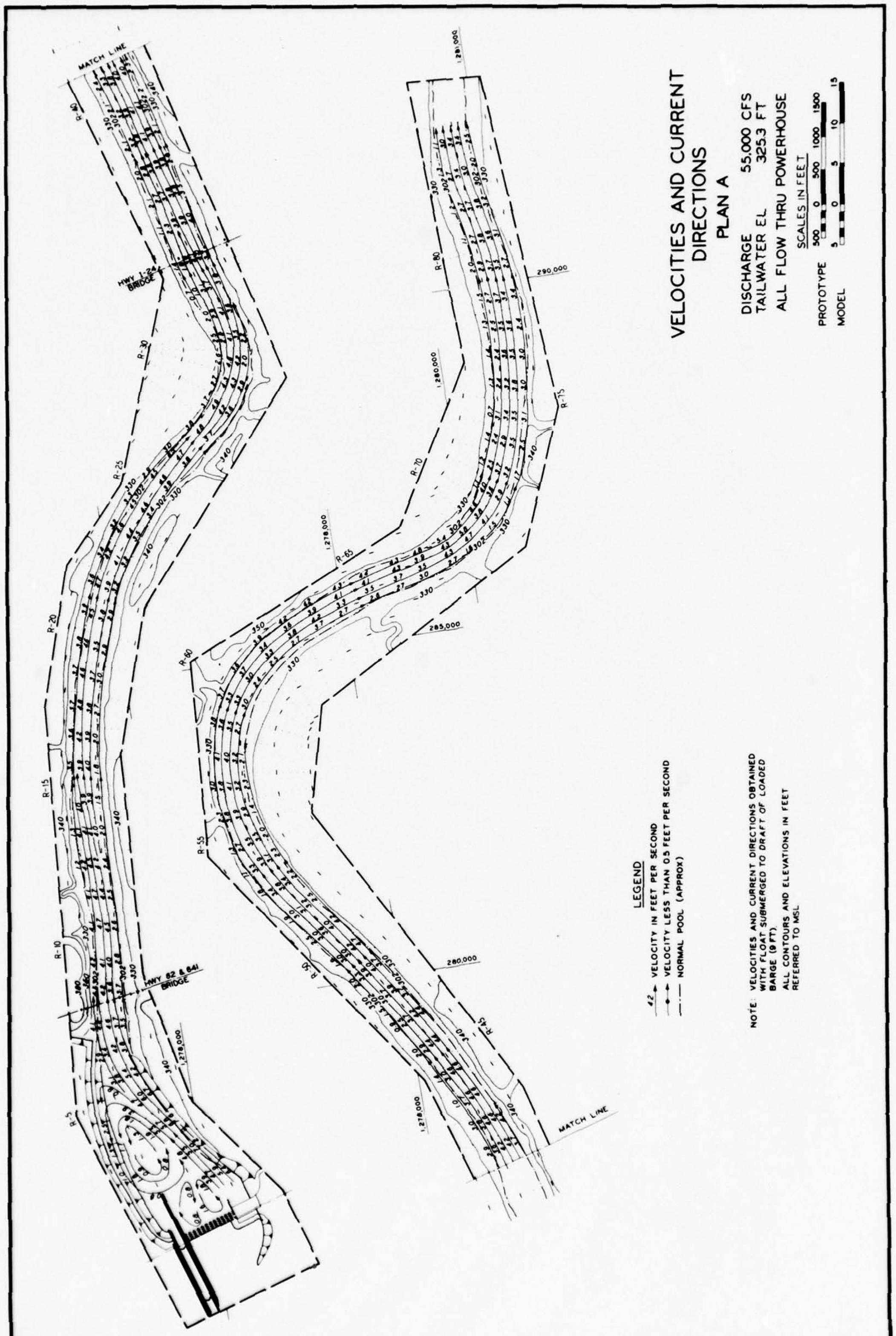
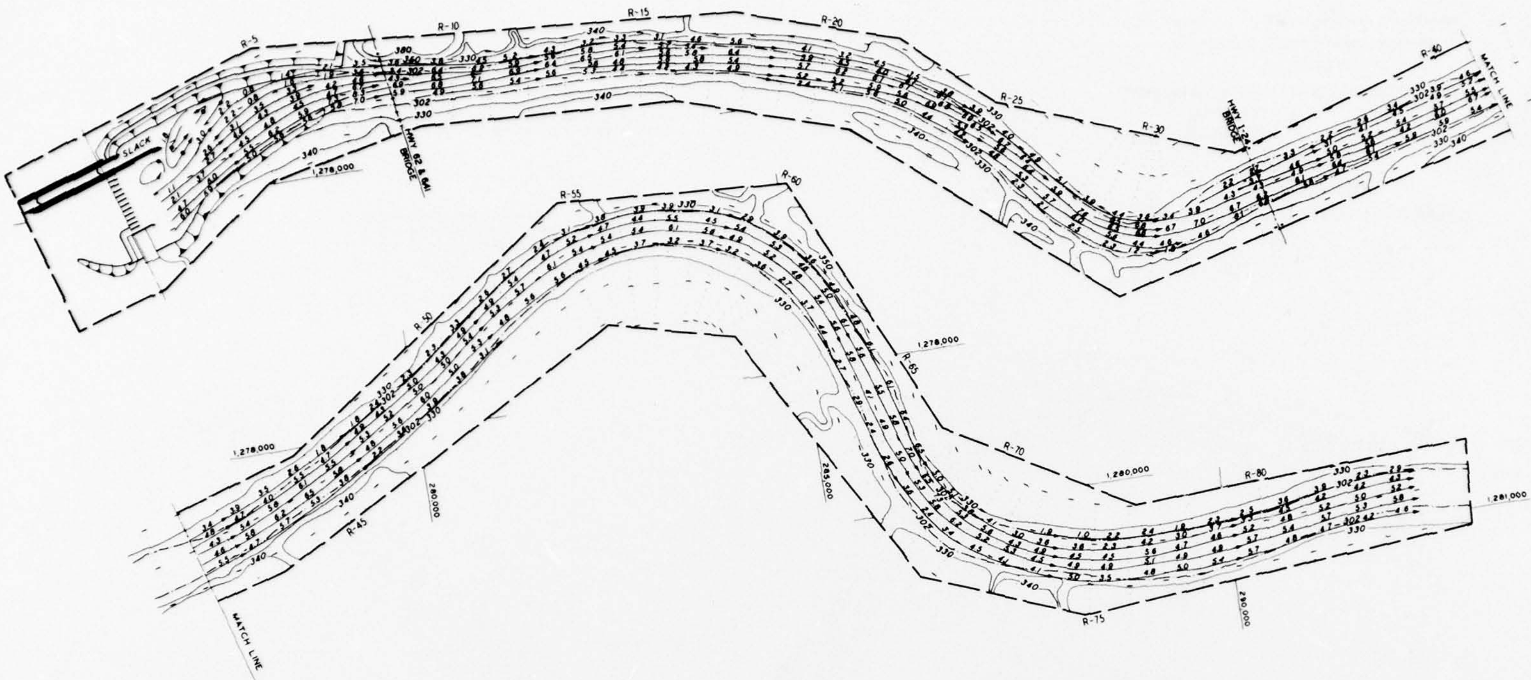

VELOCITIES AND CURRENT DIRECTIONS
PLAN A
DISCHARGE 55,000 CFS
TAILWATER EL 325.3 FT
ALL FLOW THRU POWERHOUSE
SCALES IN FEET
PROTOTYPE 500 0 500 1000 1500
MODEL 5 0 5 10 15
LEGEND
VELOCITY IN FEET PER SECOND
VELOCITY LESS THAN 0.5 FEET PER SECOND
NORMAL POOL (APPROX)
NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9 FT)
ALL CONTOURS AND ELEVATIONS IN FEET REFERRED TO MSL
MATCH LINE
HWY I-24 BRIDGE
HWY 62 & 641 BRIDGE
MATCH LINE

PLATE 26



LEGEND

- 4.2 → VELOCITY IN FEET PER SECOND
- •→ VELOCITY LESS THAN 0.5 FEET PER SECOND
- —·— NORMAL POOL (APPROX)

NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9 FT).
ALL CONTOURS AND ELEVATIONS IN FEET REFERRED TO MSL.

VELOCITIES AND CURRENT DIRECTIONS
PLAN A

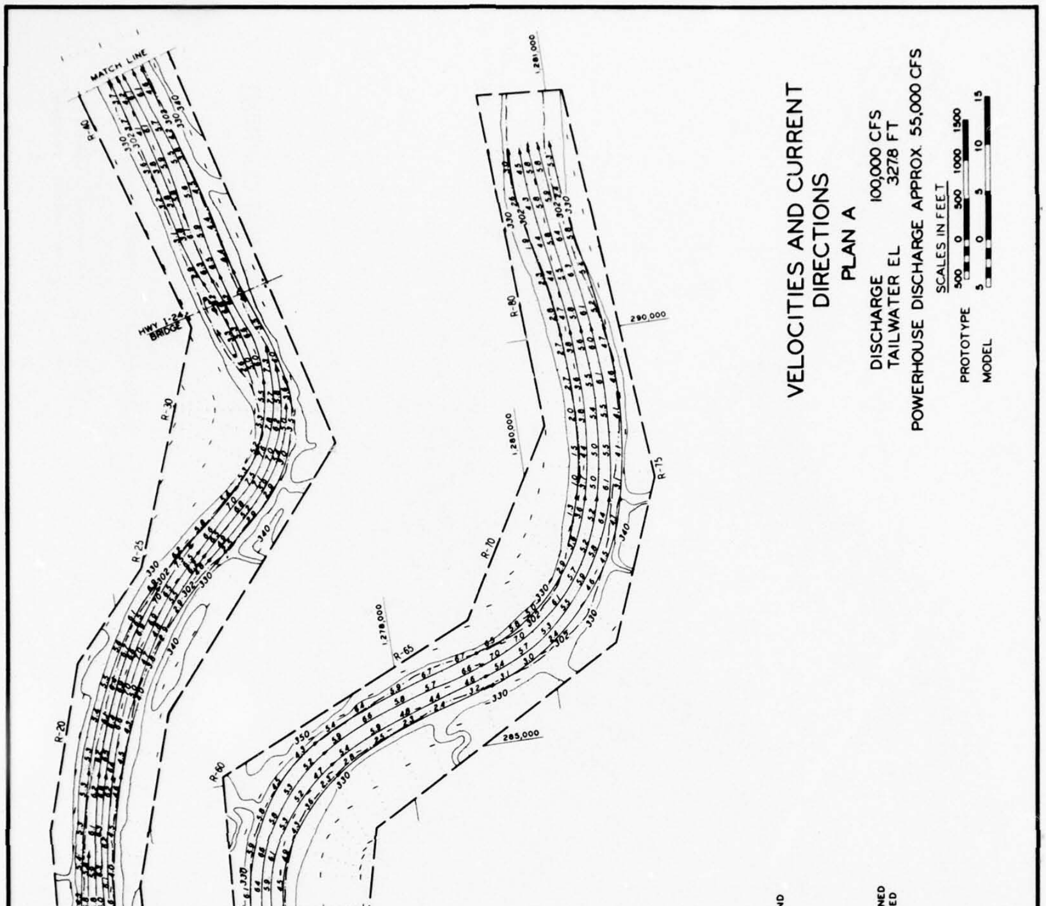
DISCHARGE	80,000 CFS
TAILWATER EL	326.5 FT

POWERHOUSE DISCHARGE APPROX. 55,000 CFS

SCALES IN FEET

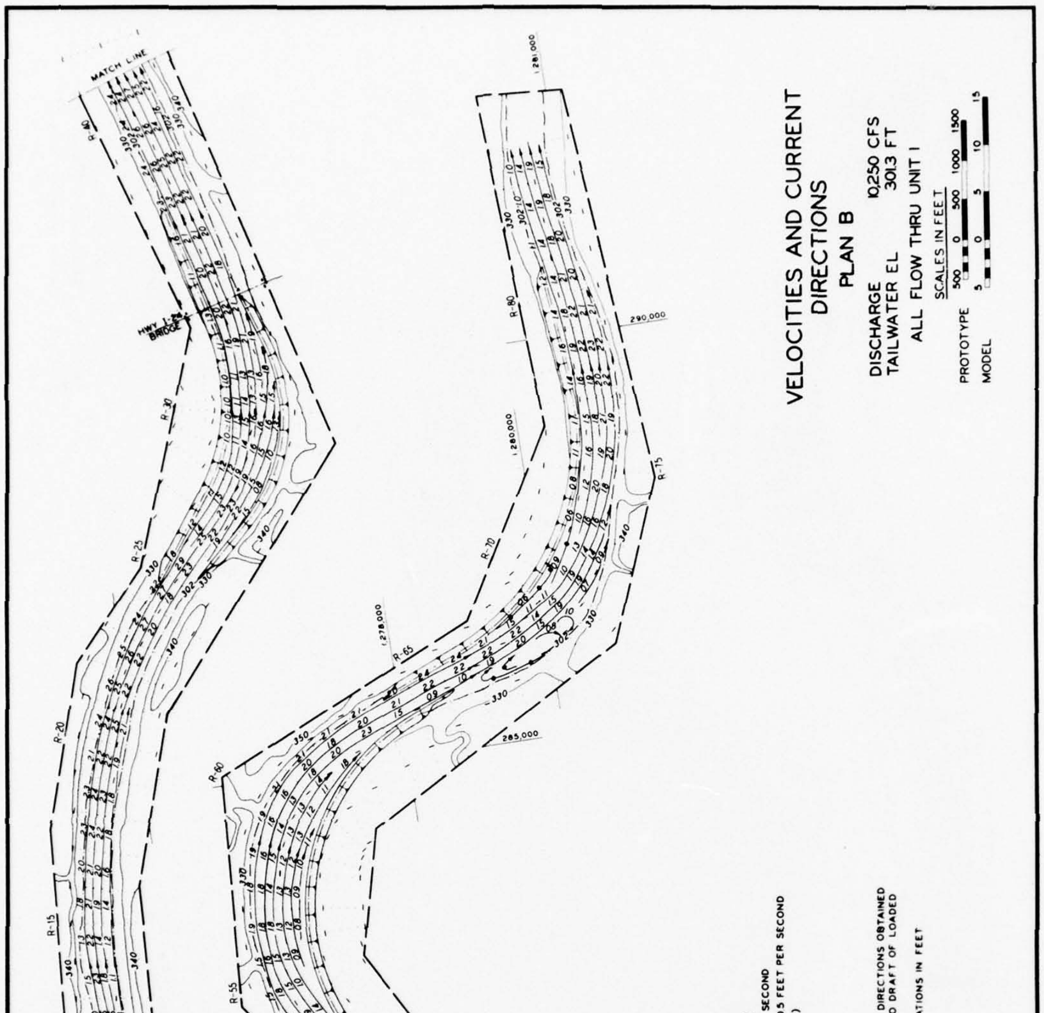
PROTOTYPE 500 0 500 1000 1500

MODEL 5 0 5 10 15



VELOCITIES AND CURRENT DIRECTIONS
PLAN A
DISCHARGE 100,000 CFS
TAILWATER EL 3278 FT
POWERHOUSE DISCHARGE APPROX. 55,000 CFS
SCALES IN FEET
PROTOTYPE 500 0 500 1000 1500
MODEL 5 0 5 10 15
LEGEND
VELOCITY IN FEET PER SECOND
VELOCITY LESS THAN 0.5 FEET PER SECOND
NORMAL POOL (APPROX)
NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9 FT).
ALL CONTOURS AND ELEVATIONS IN FEET REFERRED TO MSL
MATCH LINE
HWY I-24 BRIDGE
HWY 62 & 641 BRIDGE

PLATE 28


VELOCITIES AND CURRENT DIRECTIONS
PLAN B
DISCHARGE 10,250 CFS
TAILWATER EL 301.3 FT
ALL FLOW THRU UNIT 1
SCALES IN FEET
PROTOTYPE 500 0 500 1000 1500
MODEL 5 0 5 10 15
LEGEND
VELOCITY IN FEET PER SECOND
VELOCITY LESS THAN 0.5 FEET PER SECOND
NORMAL POOL (APPROX)
NOTE VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9 FT).
ALL CONTOURS AND ELEVATIONS IN FEET REFERRED TO MSL
MATCH LINE
HWY 62 & 641 BRIDGE
MATCH LINE

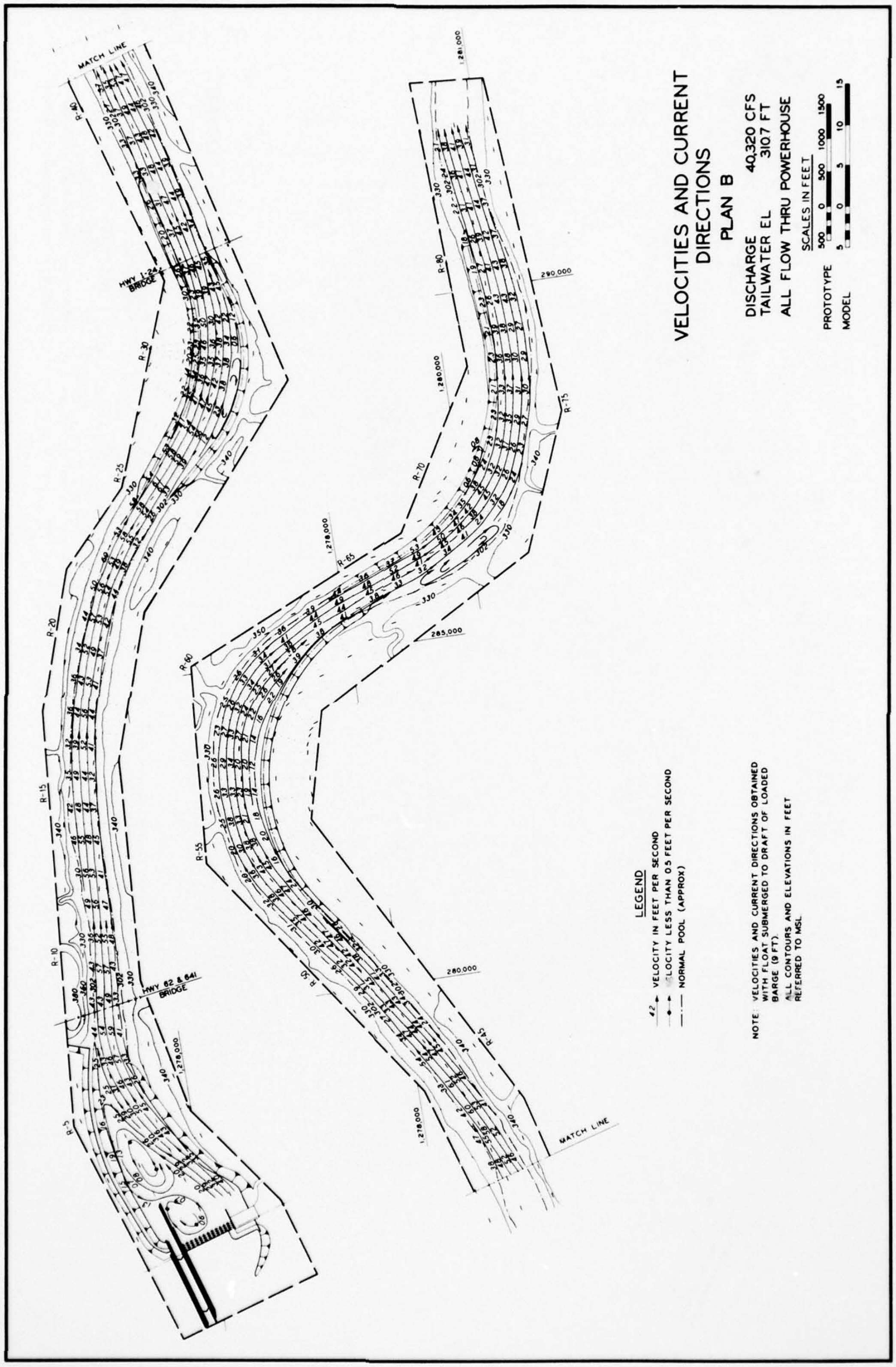
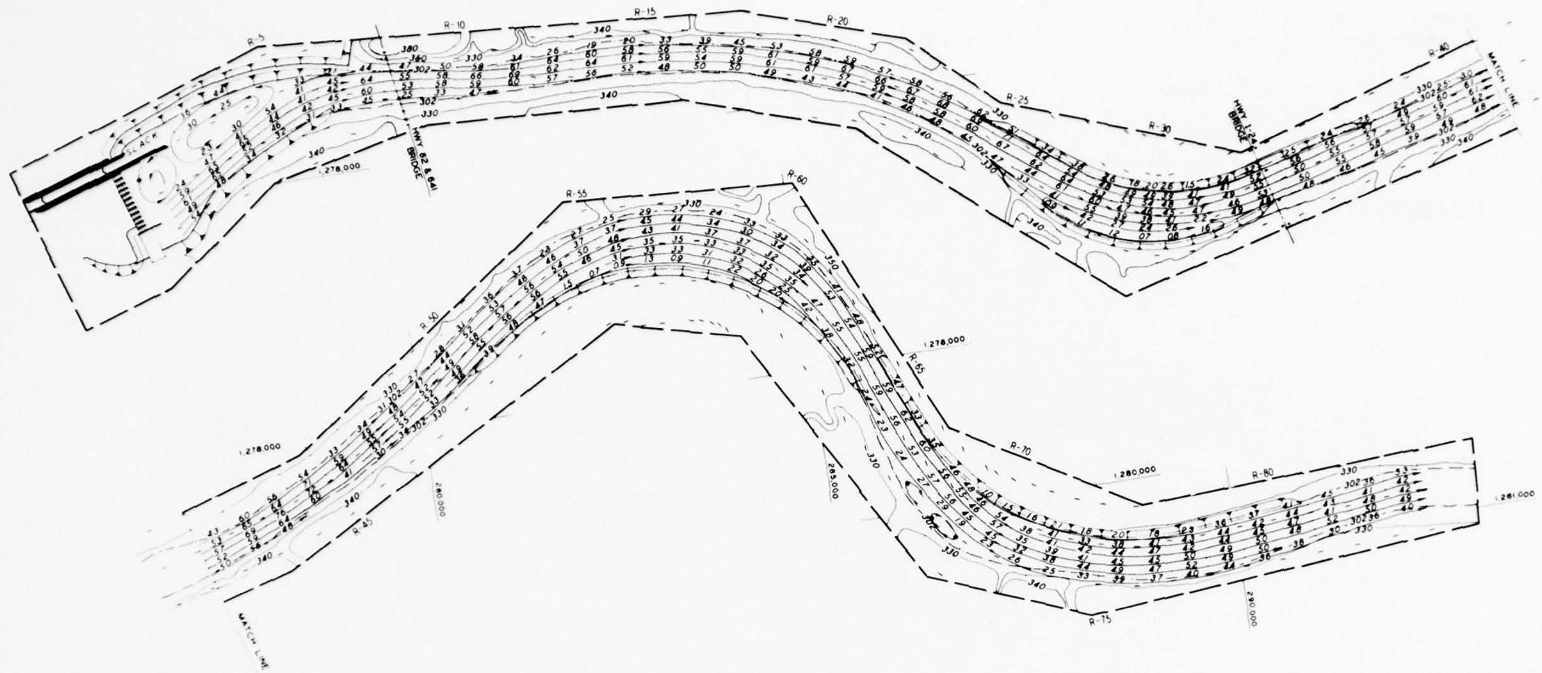

VELOCITIES AND CURRENT DIRECTIONS
PLAN B
DISCHARGE 40,320 CFS
TAILWATER EL 310.7 FT
ALL FLOW THRU POWERHOUSE
SCALES IN FEET
PROTOTYPE
MODEL
LEGEND
42 VELOCITY IN FEET PER SECOND
VELOCITY LESS THAN 0.5 FEET PER SECOND
NORMAL POOL (APPROX)
NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9 FT).
ALL CONTOURS AND ELEVATIONS IN FEET REFERRED TO MSL.
MATCH LINE
HWY I-24 BRIDGE
HWY 62 & 641 BRIDGE
MATCH LINE

PLATE 30



LEGEND

- VELOCITY IN FEET PER SECOND
- VELOCITY LESS THAN 0.5 FEET PER SECOND
- NORMAL POOL (APPROX)

NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9FT).
ALL CONTOURS AND ELEVATIONS IN FEET REFERRED TO MSL.

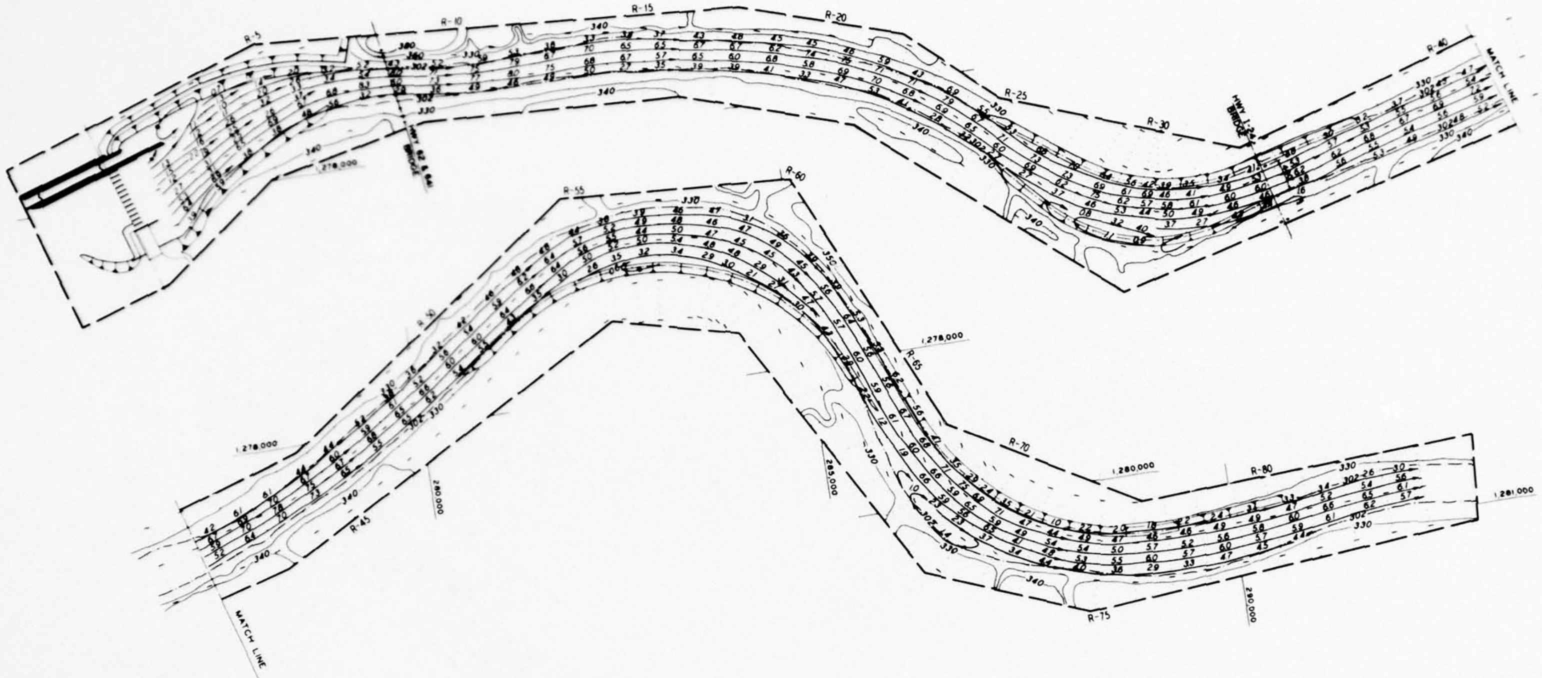
VELOCITIES AND CURRENT DIRECTIONS
PLAN B

DISCHARGE 55,000 CFS
TAILWATER EL 314.0 FT
ALL FLOW THRU POWERHOUSE

SCALES IN FEET

PROTOTYPE 500 0 500 1000 1500
MODEL 5 0 5 10 15

PLATE 31



LEGEND

42 → VELOCITY IN FEET PER SECOND

→ VELOCITY LESS THAN 0.5 FEET PER SECOND

— · — NORMAL POOL (APPROX)

NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9 FT)

ALL CONTOURS AND ELEVATIONS IN FEET REFERRED TO MSL

VELOCITIES AND CURRENT DIRECTIONS

PLAN B

DISCHARGE 80,000 CFS

TAILWATER EL 320.7 FT

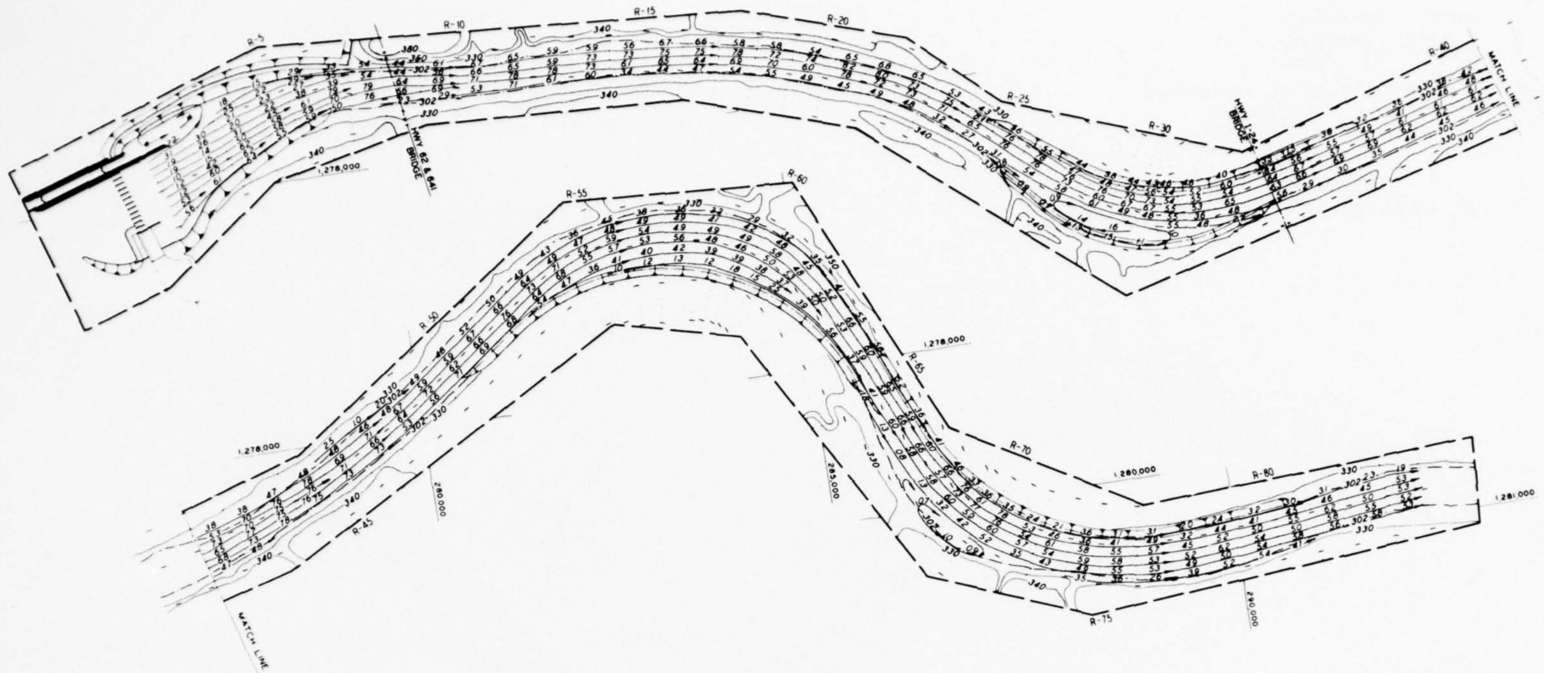
POWERHOUSE DISCHARGE APPROX. 55,000 CFS

SCALES IN FEET

PROTOTYPE 500 0 500 1000 1500

MODEL 5 0 5 10 15

PLATE 32



LEGEND

42 → VELOCITY IN FEET PER SECOND

→ VELOCITY LESS THAN 0.5 FEET PER SECOND

NORMAL POOL (APPROX)

NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9 FT).

ALL CONTOURS AND ELEVATIONS IN FEET REFERRED TO MSL

VELOCITIES AND CURRENT DIRECTIONS
PLAN B

DISCHARGE 100,000 CFS
TAILWATER EL 325.2 FT
POWERHOUSE DISCHARGE APPROX. 55,000 CFS

SCALES IN FEET

PROTOTYPE 500 0 500 1000 1500

MODEL 5 0 5 10 15

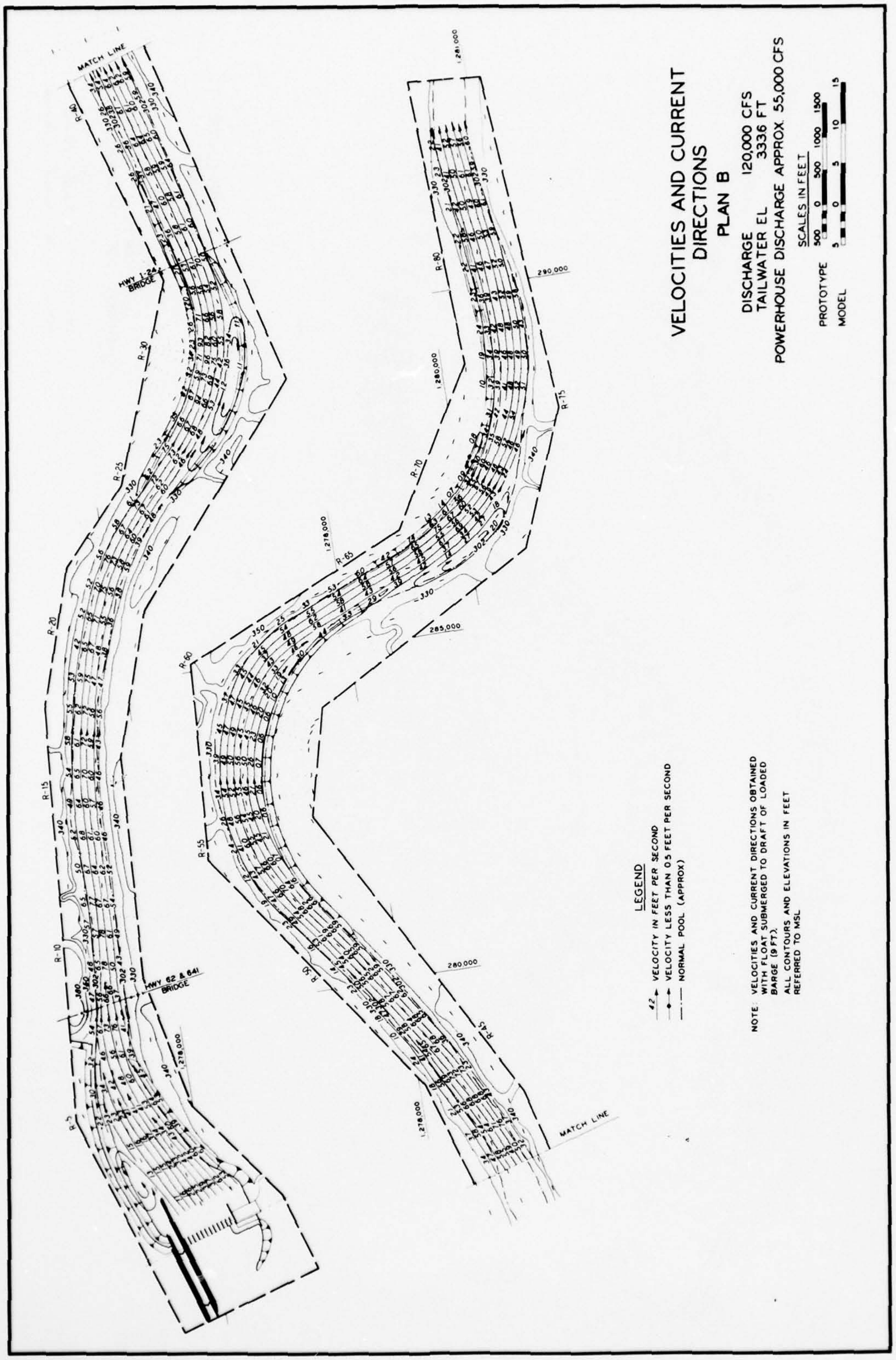
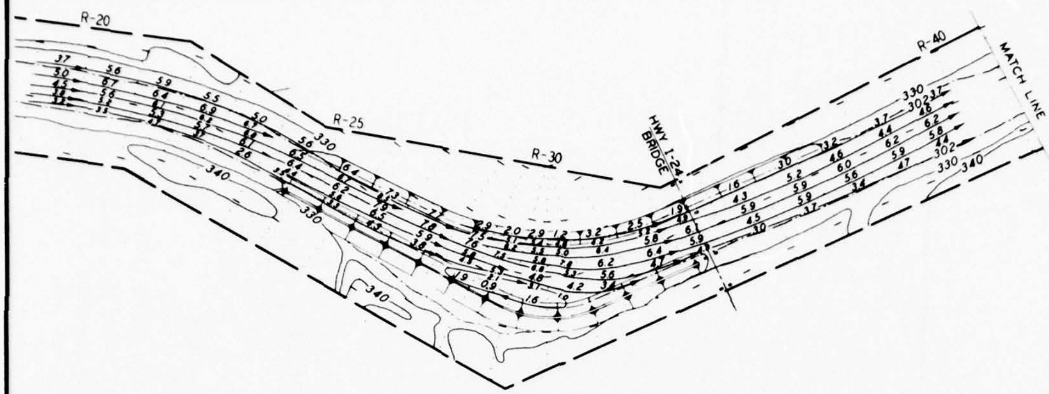
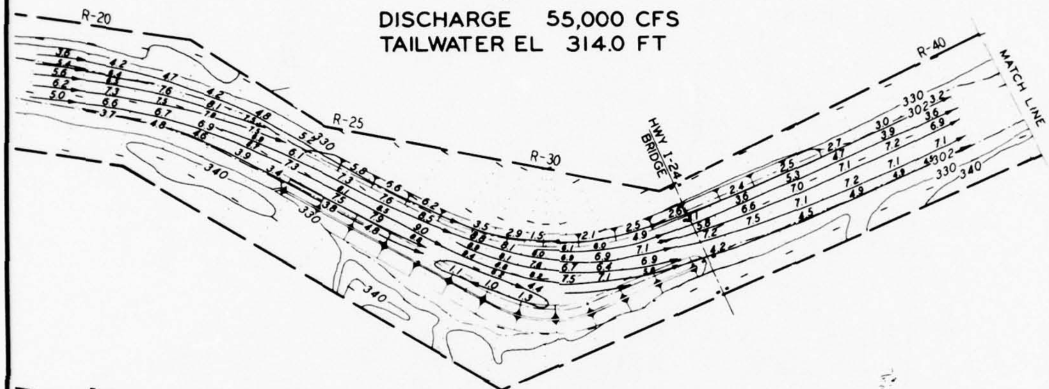

VELOCITIES AND CURRENT DIRECTIONS
PLAN B
DISCHARGE 120,000 CFS
TAILWATER EL 333.6 FT
POWERHOUSE DISCHARGE APPROX. 55,000 CFS
SCALES IN FEET
PROTOTYPE 500 0 500 1000 1500
MODEL 5 0 5 10 15
LEGEND
42 VELOCITY IN FEET PER SECOND
VELOCITY LESS THAN 0.5 FEET PER SECOND
NORMAL POOL (APPROX)
NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9 FT).
ALL CONTOURS AND ELEVATIONS IN FEET REFERRED TO MSL
MATCH LINE
HWY I-24 BRIDGE
HWY 62 & 641 BRIDGE
MATCH LINE
R-5
R-10
R-15
R-20
R-25
R-30
R-40
R-45
R-50
R-55
R-60
R-65
R-70
R-75
R-80
1,278,000
1,280,000
1,281,000
280,000
285,000
290,000

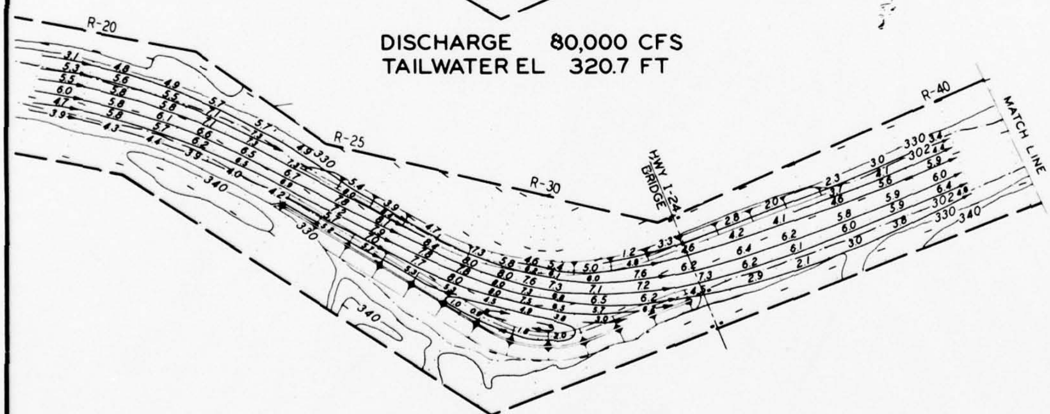
PLATE 34



DISCHARGE 55,000 CFS
TAILWATER EL 314.0 FT



DISCHARGE 80,000 CFS
TAILWATER EL 320.7 FT



DISCHARGE 120,000 CFS
TAILWATER EL 333.6 FT

VELOCITIES AND CURRENT DIRECTIONS

PLAN B-MODIFIED

DISCHARGES 55,000, 80,000, AND 120,000 CFS

POWERHOUSE DISCHARGE APPROX. 55,000 CFS

LEGEND

- 42 → VELOCITY IN FEET PER SECOND
- VELOCITY LESS THAN 0.5 FEET PER SECOND
- NORMAL POOL (APPROX)

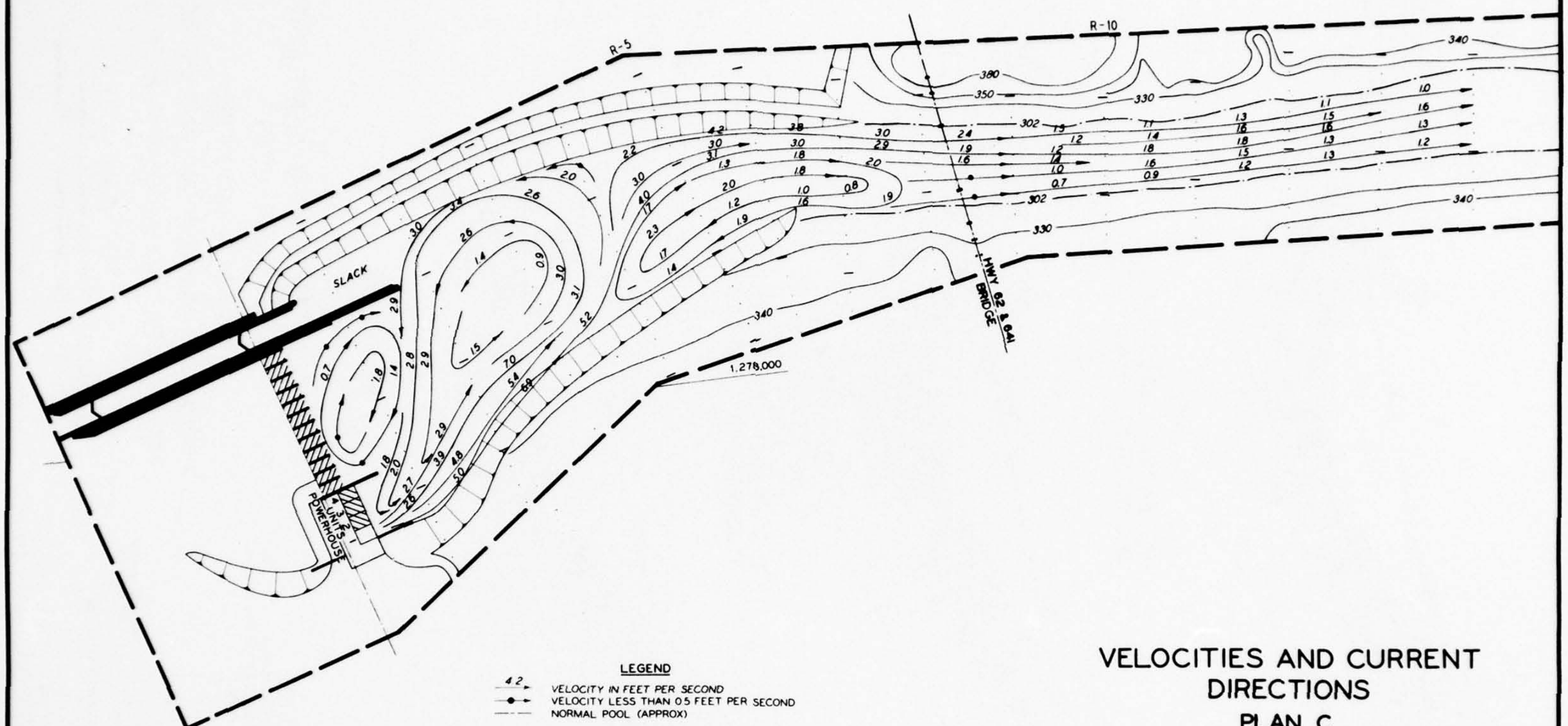
NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9FT).
ALL CONTOURS AND ELEVATIONS IN FEET REFERRED TO MSL.

SCALES IN FEET

PROTOTYPE 500 0 500 1000 1500

MODEL 5 0 5 10 15

PLATE 35



LEGEND

- 4.2 → VELOCITY IN FEET PER SECOND
- ●→ VELOCITY LESS THAN 0.5 FEET PER SECOND
- — · — NORMAL POOL (APPROX)

NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9 FT)
ALL CONTOURS AND ELEVATIONS IN FEET REFERRED TO MSL

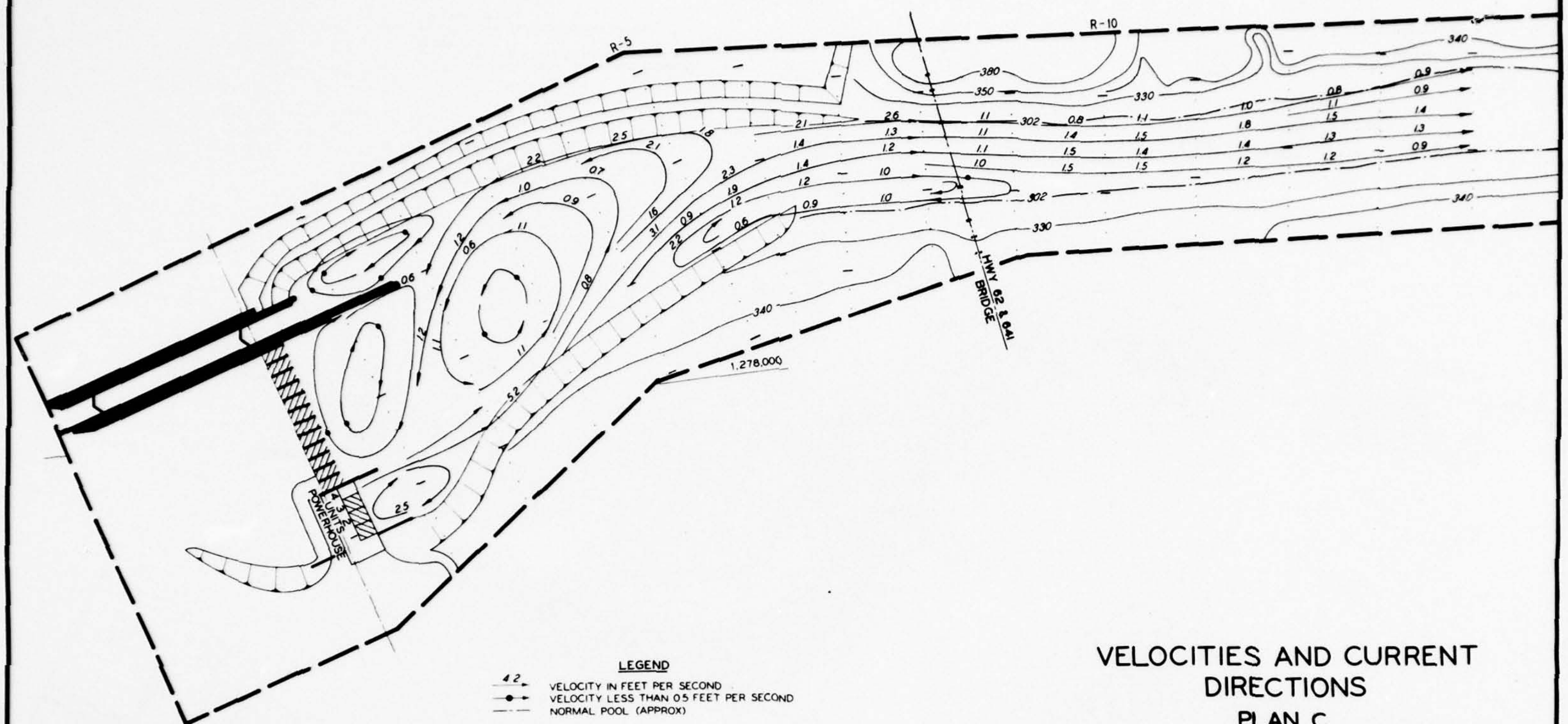
VELOCITIES AND CURRENT DIRECTIONS
PLAN C

DISCHARGE 10,250 CFS
TAILWATER EL 311.0 FT

ALL FLOW THRU UNIT 1

SCALES IN FEET

PROTOTYPE 500 0 500 1000
MODEL 5 0 5 10



LEGEND

- 4.2 → VELOCITY IN FEET PER SECOND
- → VELOCITY LESS THAN 0.5 FEET PER SECOND
- — · — NORMAL POOL (APPROX)

NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9 FT)
ALL CONTOURS AND ELEVATIONS IN FEET REFERRED TO MSL

VELOCITIES AND CURRENT DIRECTIONS
PLAN C

DISCHARGE 10,250 CFS
TAILWATER EL 311.0 FT

ALL FLOW THRU UNIT 4

SCALES IN FEET

PROTOTYPE 500 0 500 1000
MODEL 5 0 5 10

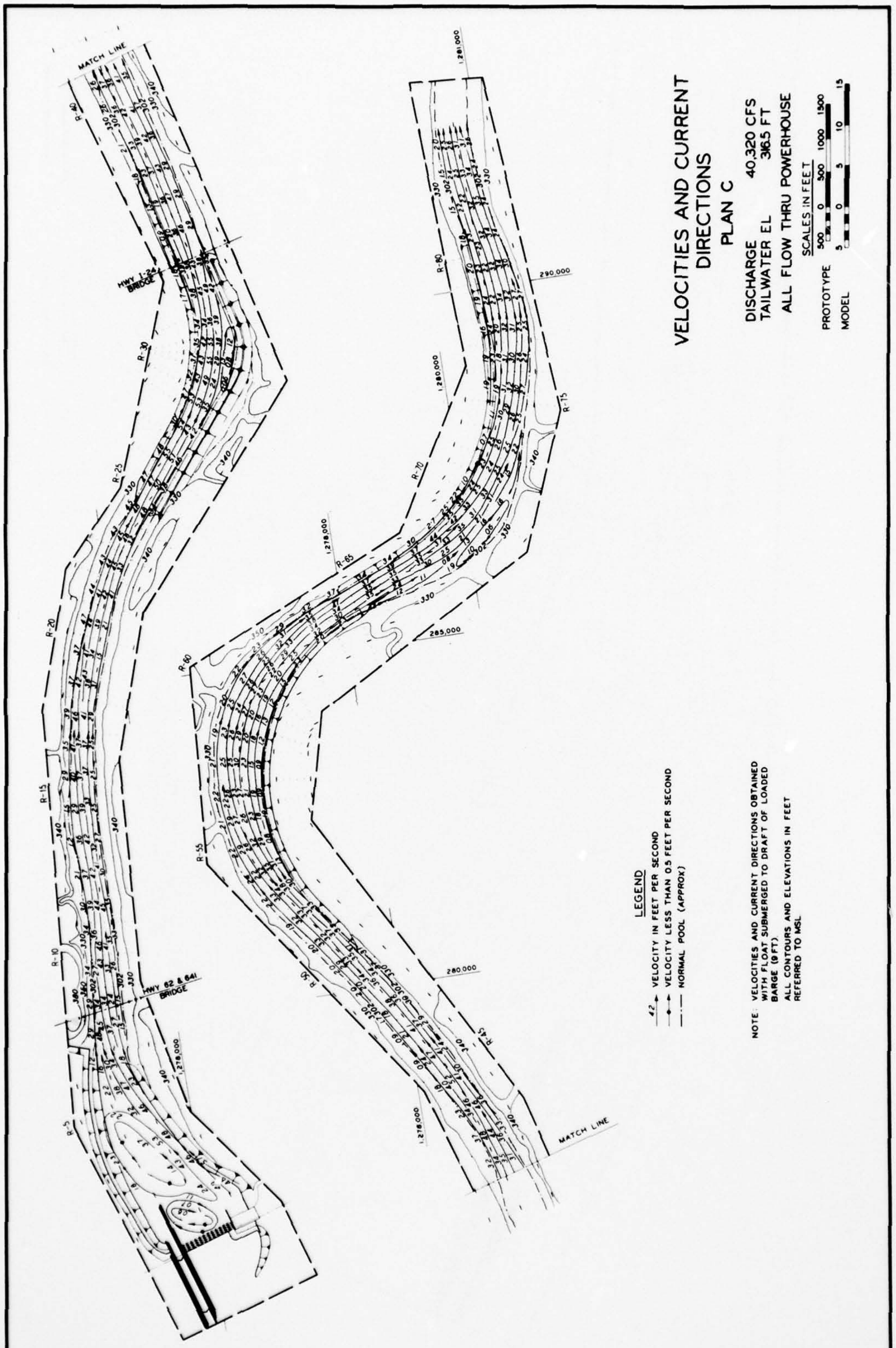
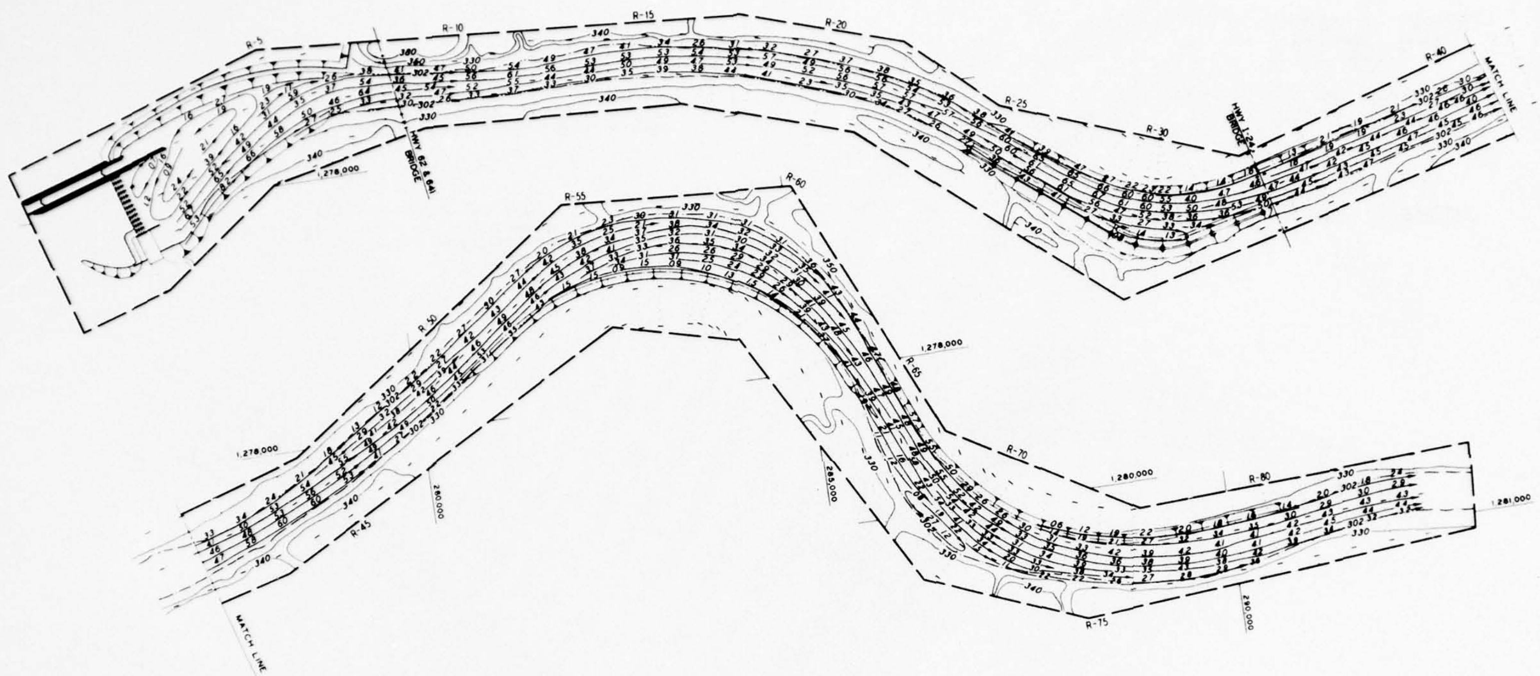

VELOCITIES AND CURRENT DIRECTIONS
PLAN C
DISCHARGE 40,320 CFS
TAILWATER EL 316.5 FT
ALL FLOW THRU POWERHOUSE
SCALES IN FEET
PROTOTYPE 500 0 500 1000 1500
MODEL 5 0 5 10 15
LEGEND
42 VELOCITY IN FEET PER SECOND
VELOCITY LESS THAN 0.5 FEET PER SECOND
NORMAL POOL (APPROX)
NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9 FT)
ALL CONTOURS AND ELEVATIONS IN FEET REFERRED TO MSL
MATCH LINE
HWY I-244 BRIDGE
HWY 62 & 64 BRIDGE
MATCH LINE

PLATE 38



LEGEND

42 → VELOCITY IN FEET PER SECOND

→•→ VELOCITY LESS THAN 0.5 FEET PER SECOND

—·— NORMAL POOL (APPROX)

NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9 FT)

ALL CONTOURS AND ELEVATIONS IN FEET REFERRED TO MSL

VELOCITIES AND CURRENT DIRECTIONS
PLAN C

DISCHARGE 55,000 CFS
TAILWATER EL 318.6 FT
ALL FLOW THRU POWERHOUSE

SCALES IN FEET

PROTOTYPE 500 0 500 1000 1500

MODEL 5 0 5 10 15

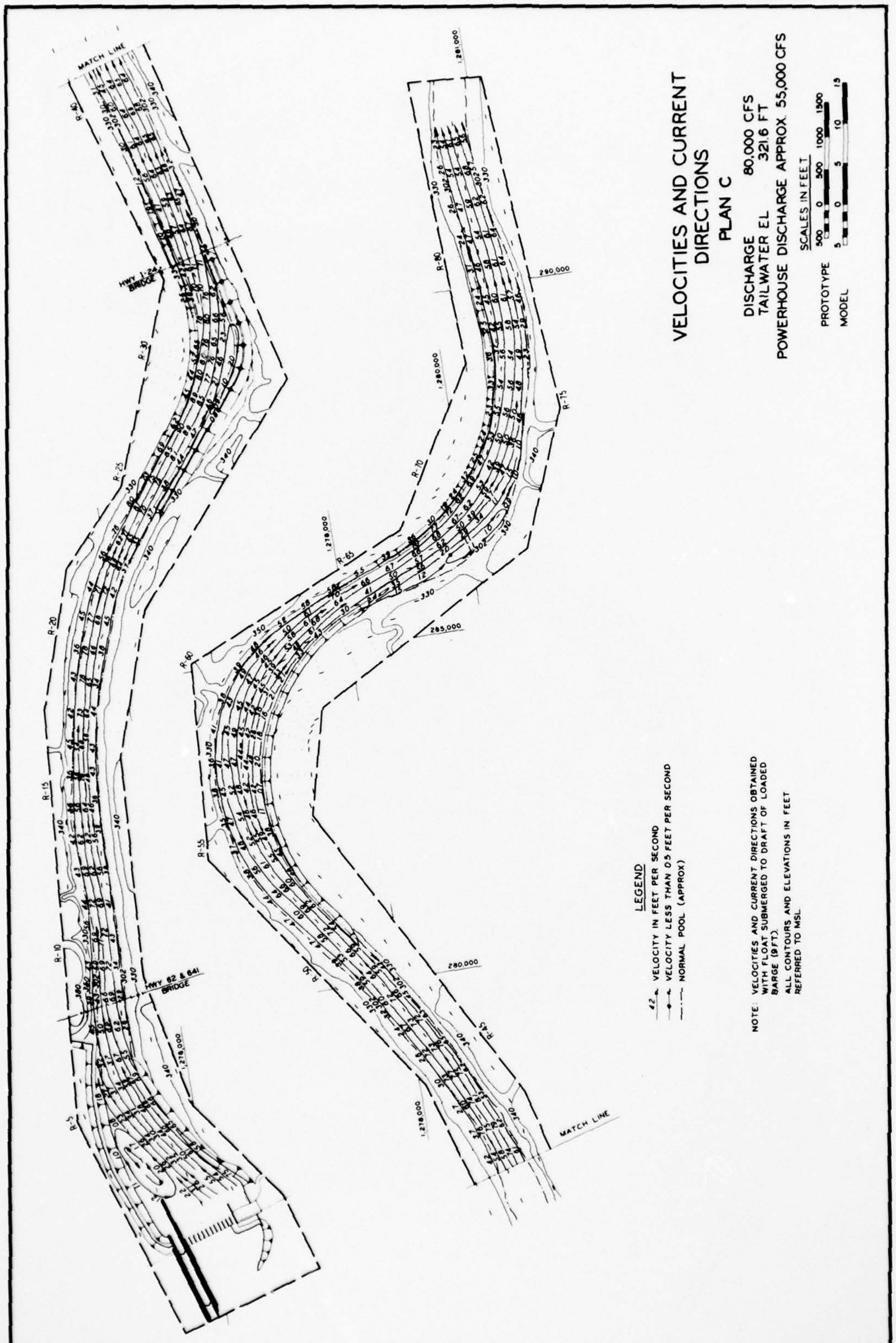
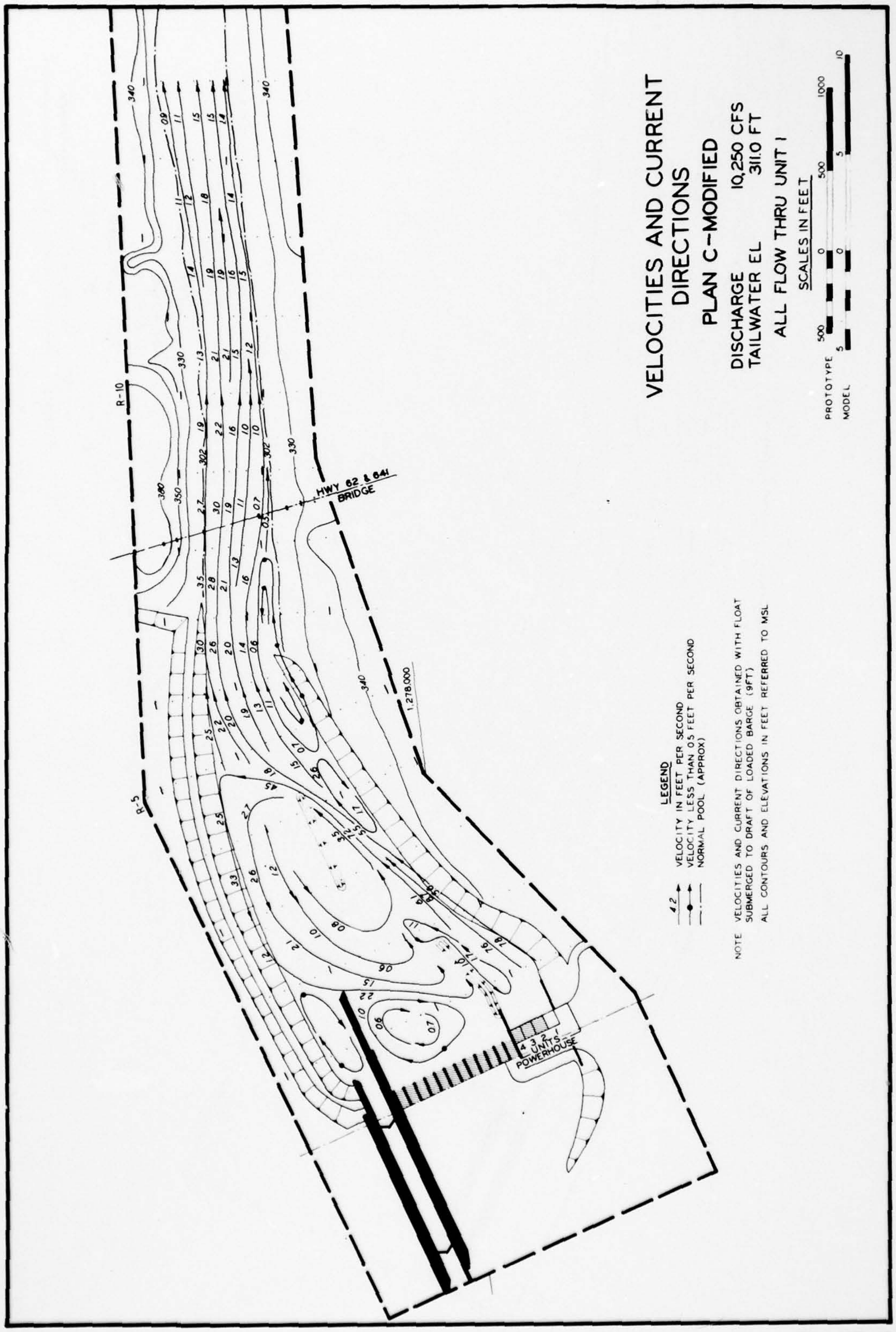

VELOCITIES AND CURRENT DIRECTIONS
PLAN C
DISCHARGE 80,000 CFS
TAILWATER EL 321.6 FT
POWERHOUSE DISCHARGE APPROX 55,000 CFS
SCALES IN FEET
PROTOTYPE
MODEL
LEGEND
42 VELOCITY IN FEET PER SECOND
VELOCITY LESS THAN 0.5 FEET PER SECOND
NORMAL POOL (APPROX)
NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9 FT).
ALL CONTOURS AND ELEVATIONS IN FEET REFERRED TO MSL.
MATCH LINE
HWY 1-24 BRIDGE
HWY 62 & 641 BRIDGE
MATCH LINE

PLATE 40

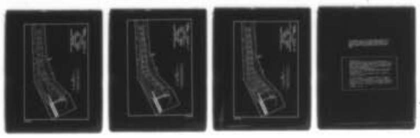


VELOCITIES AND CURRENT DIRECTIONS
PLAN C-MODIFIED
DISCHARGE 10,250 CFS
TAILWATER EL 311.0 FT
ALL FLOW THRU UNIT 1
SCALES IN FEET
PROTOTYPE 500 0 500 1000
MODEL 5 0 5 10
LEGEND
4.2 VELOCITY IN FEET PER SECOND
VELOCITY LESS THAN 0.5 FEET PER SECOND
NORMAL POOL (APPROX)
NOTE VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9FT)
ALL CONTOURS AND ELEVATIONS IN FEET REFERRED TO MSL
HWY 62 & 641 BRIDGE
R-10
R-5
1,278,000
4 3 2 1 UNITS
POWERHOUSE

AD-A068 618 ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MISS F/G 13/10
NAVIGATION CONDITIONS ON THE LOWER CUMBERLAND RIVER, KENTUCKY; --ETC(U)
MAR 79 L J SHOWS, J J FRANCO

UNCLASSIFIED WES-TR-HL-79-7 NL

2 OF 2
AD
A068618



END
DATE
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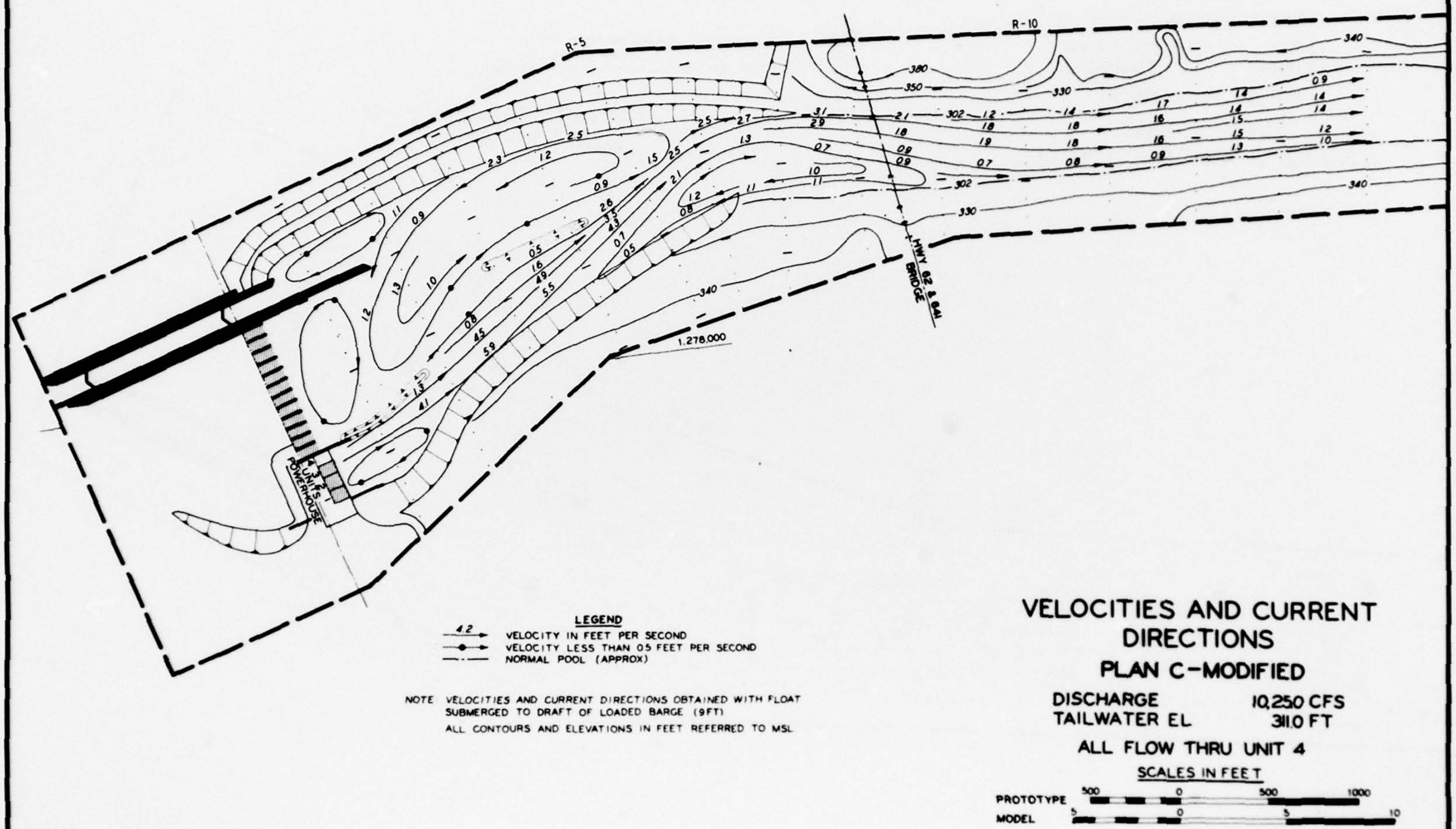


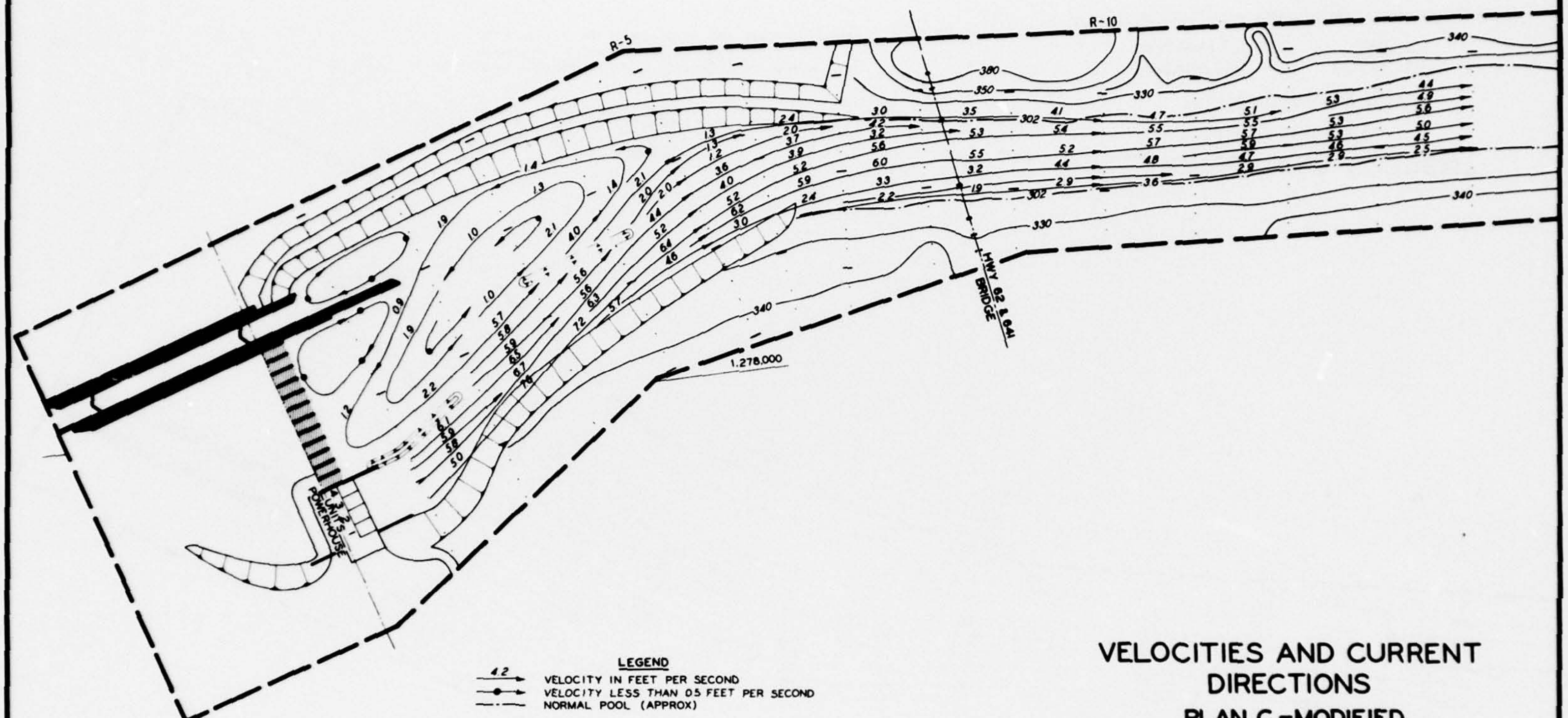
VELOCITIES AND CURRENT DIRECTIONS

PLAN C-MODIFIED

DISCHARGE 10,250 CFS
TAILWATER EL 311.0 FT

ALL FLOW THRU UNIT 4

PLATE 42



LEGEND

4.2 → VELOCITY IN FEET PER SECOND
—•— VELOCITY LESS THAN 0.5 FEET PER SECOND
—·— NORMAL POOL (APPROX)

NOTE VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9FT)

ALL CONTOURS AND ELEVATIONS IN FEET REFERRED TO MSL

VELOCITIES AND CURRENT DIRECTIONS

PLAN C-MODIFIED

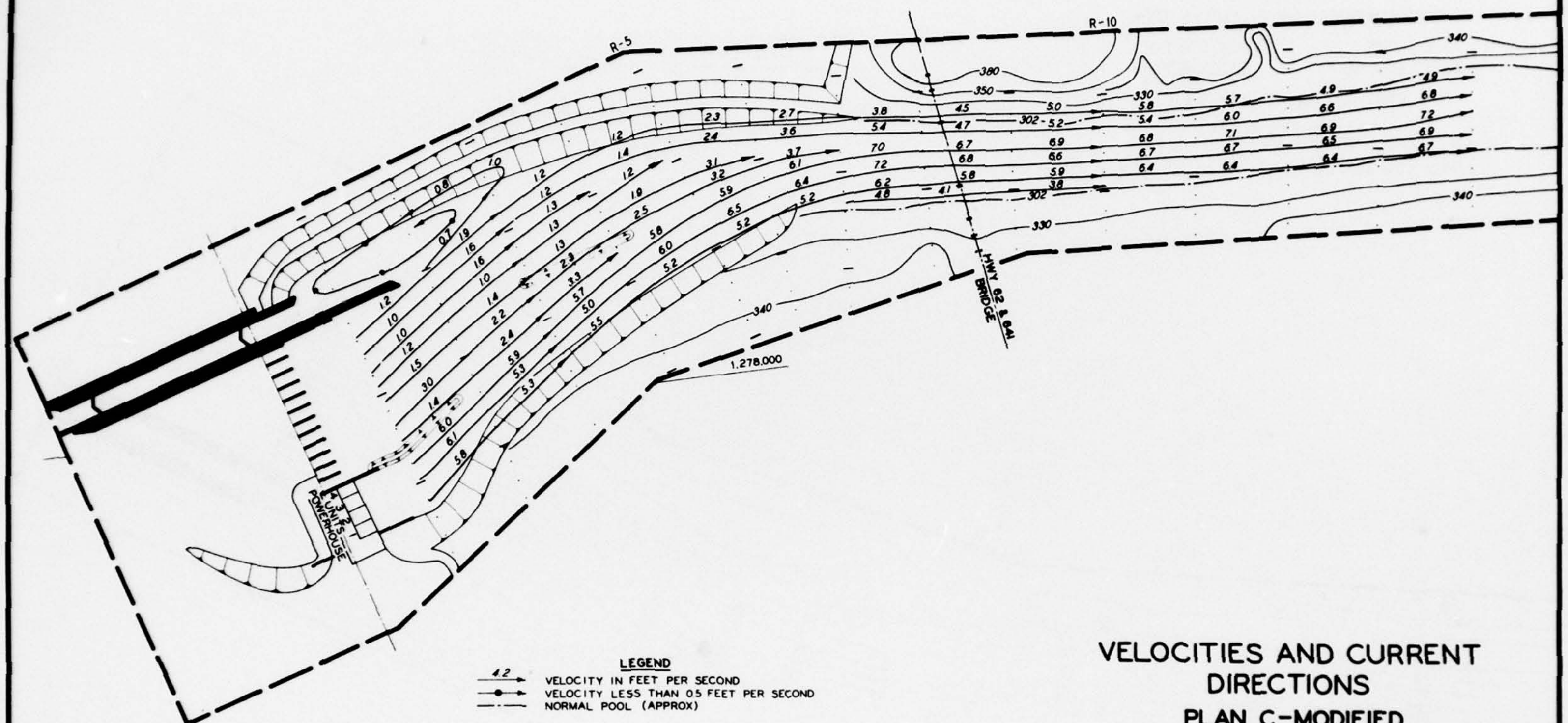
DISCHARGE	55,000 CFS
TAILWATER EL	318.6 FT

ALL FLOW THRU POWERHOUSE

SCALES IN FEET

PROTOTYPE 500 0 500 1000

MODEL 5 0 5 10



LEGEND

- 4.2 → VELOCITY IN FEET PER SECOND
- —•→ VELOCITY LESS THAN 0.5 FEET PER SECOND
- —·— NORMAL POOL (APPROX)

NOTE VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9FT)
ALL CONTOURS AND ELEVATIONS IN FEET REFERRED TO MSL.

VELOCITIES AND CURRENT DIRECTIONS

PLAN C-MODIFIED

DISCHARGE 80,000 CFS
TAILWATER EL 321.6 FT
POWERHOUSE DISCHARGE APPROX. 55,000 CFS

SCALES IN FEET

PROTOTYPE 500 0 500 1000
MODEL 5 0 5 10

PLATE 44

In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

Shows, Louis J
Navigation conditions on the lower Cumberland River, Kentucky; hydraulic model investigation / by Louis J. Shows, John J. Franco. Vicksburg, Miss. : U. S. Waterways Experiment Station ; Springfield, Va. : available from National Technical Information Service, 1979.
32, [19] p., 44 leaves of plates : ill. : 27 cm. (Technical report - U. S. Army Engineer Waterways Experiment Station ; HL-79-7)
Prepared for U. S. Army Engineer District, Nashville, Nashville, Tennessee.

1. Cumberland River. 2. Fixed-bed models. 3. Hydraulic models. 4. Navigation conditions. I. Franco, John J., joint author. II. United States. Army. Corps of Engineers. Nashville District. III. Series: United States. Waterways Experiment Station, Vicksburg, Miss. Technical report ; HL-79-7.
TA7.W34 no.HL-79-7